FEASIBILITY OF FUEL PEAT PRODUCTION AND UTILIZATION AT HAY RIVER AND YELLOWKNIFE, N.W.T.

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FEASIBILITY OF FUEL PEAT PRODUCTION AND UTILIZATION AT HAY RIVER AND YELLOWKNIFE, N.W.T.

SUMMARY

Peat has been used as fuel for many years in other northern countries, but has not yet been used for this purpose in northern Canada, although large deposits are found here. The technology for fuel peat production and utilization is well developed in Europe, Scandinavia, and the Soviet Union, and horticultural peat has been harvested for many years in southern Canada, but it is not known whether this technology would be directly applicable to Canadian communities in the north. Factors such as permafrost, size of energy market, and climate make it necessary to evaluate the existing technology in terms of these local constraints.

A preliminary inspection of airphotos of peatlands near several northern communities revealed that the peat deposits near Hay River and Yellowknife show the most promise for potential development. The reasons for selection of these two communities are given, with an assessment of the suitability of the nearby peat resources for harvesting and utilization based partly on findings and observations during visits to the sites.

Secondly, the feasibility of fuel peat production at Hay River and Yellowknife is addressed. The technical and economic aspects of fuel peat production in relation to the estimated initial market for fuel peat are discussed.

The third part of the report examines the technical and economic aspects of fuel peat combustion with reference to Hay River and Yellowknife based on information from Finland where the technology of fuel peat combustion is well established.

The discussion of peat production and combustion systems is supported by the latest information gathered during a recent visit to Finland. During the visit, several peat harvesting operations and peat-fired heating plants were examined, and peat producers, peat machinery manufacturers, peat-fired boiler manufacturers, and fuel peat consumers were interviewed.

The report also contains the results of extensive calculations of cost and performance estimates of fuel peat production and combustion at Hay River and Yellowknife.

The study found that fuel peat production and utilization in Hay River and Yellowknife would be technically feasible, favoring Hay River, subject to confirmation

of quality and quantity of the peat resource and any unforeseen problems from local conditions like permafrost. If produced in quantity, fuel peat should be much cheaper than other fuels, and the cost of heat produced with peat should be only slightly more expensive than if produced from other fuels. As actual costs cannot be precisely predicted, they could only be determined through actual experience. The potential benefits of having a local secure supply of fuel, added local employment, and stimulation of the local economy arising from peat fuel production and utilization are additional attractions.

For these reasons, it is recommended that a demonstration peat production and utilization project be initiated at Hay River. There would be five main objectives:

- To confirm the quality and quantity of the fuel peat resource.
- To evaluate the performance of existing peat production technology under local conditions at Hay River.
- To determine actual cost of fuel peat production under local conditions.
- To determine the cost of heat production using fuel peat under local conditions.
- To expose technical advantages and difficulties of heat production using fuel peat under local conditions.

FAISABILITÉ DE L'EXTRACTION ET DE L'UTILISATION DE LA TOURBE COMME COMBUSTIBLE À HAY RIVER ET À YELLOWKNIFE (T.N.-O.)

Résumé

Depuis de nombreuses années déjà, la tourbe est utilisée comme combustible dans d'autres pays nordiques, mais elle n'a jamais été utilisée à cette fin dans le Nord canadien, bien que l'on y trouve d'importants gisements. Les techniques d'extraction et d'utilisation du combustible-tourbe sont très avancées en Europe, en Scandinavie et en Union soviétique, et la tourbe est exploitée depuis longtemps à des fins d'horticulture dans le Sud du Canada, mais on ne sait pas encore si les techniques actuelles pourront être appliquées directement aux collectivités du Nord. Des facteurs tels que le pergélisol, la faible demande énergétique et le climat obligent à évaluer les techniques à la lumière de ces restrictions d'ordre local.

Une inspection préliminaire des photos aériennes de tourbières situées à proximité de plusieurs collectivités du Nord a révélé que les gisements de tourbe se trouvant près de Hay River et de Yellowknife offrent les meilleures possibilités d'exploitation commerciale. On donne dans la première partie du rapport les raisons motivant le choix de ces deux collectivités, ainsi qu'une évaluation des possibilités d'extraction et d'utilisation des ressources locales en tourbe. Cette évaluation repose en partie sur les observations et les constatations effectuées lors des visites sur le terrain.

Dans la deuxième partie, on aborde la question de la faisabilité de l'extraction du combustible-tourbe à Hay River et à Yellowknife, ainsi que les facteurs techniques et économiques liés à l'exploitation de ce combustible en fonction du marché initial prévu qu'il aurait.

La troisième partie du rapport traite des aspects économiques et techniques liés à la combustion de la tourbe en ce qui concerne Hay River et Yellowknife, d'après les renseignements obtenus en Finlande, où les techniques de combustion de la tourbe sont bien établies.

La discussion portant sur les systèmes d'extraction et de combustion de la tourbe est étayée par les données récemment recueillies lors d'une visite en Finlande. Au cours de cette visite, plusieurs exploitations d'extraction de tourbe et installations de chauffage alimentées à la tourbe ont été examinées, et des exploitants de gisements de tourbe, des fabricants de machines et de chaudières alimentées à la tourbe ainsi que des consommateurs de combustible-tourbe ont été interviewés.

Le rapport comprend également des calculs détaillés du rendement et des coûts prévus de l'extraction et de la combustion de la tourbe à Hay River et à Yellowknife.

Dans l'étude, on conclut que l'extraction et l'utilisation de la tourbe comme combustible seraient techniquement faisables à Hay River et à Yellowknife, de préférence à Hay River, sous réserve de confirmation de la qualité et de la quantité des ressources disponibles et à condition de trouver des solutions aux problèmes imprévus qui peuvent découler de conditions locales telles que le pergélisol. Le combustible-tourbe devrait coûter nettement moins cher que d'autres combustibles, à condition que l'extraction soit entreprise en grande quantité. Le coût du chauffage à la tourbe ne devrait dépasser que faiblement le coût du chauffage à l'aide d'autres combustibles. Les coûts réels ne peuvent être déterminés que dans la pratique. L'existence d'une source sûre de combustible sur place, l'accroissement du nombre d'emplois et la stimulation de l'économie locale entraînée par l'extraction et l'utilisation de la tourbe représentent des avantages supplémentaires.

Par conséquent, il est recommandé d'entreprendre à Hay River, un projet pilote d'extraction et d'utilisation de la tourbe qui comporterait cinq objectifs principaux:

- confirmer la qualité et la quantité des réserves de combustible-tourbe;
- évaluer les techniques actuelles d'extraction de la tourbe dans les conditions prévalant à Hay River;
- déterminer les coûts réels d'extraction du combustible-tourbe dans des conditions locales;
- déterminer les coûts de production d'énergie au moyen de la tourbe dans des conditions locales; et
- faire ressortir les avantages et les inconvénients d'ordre technique de la production d'énergie au moyen du combustible-tourbe dans des conditions locales.

Cette étude a été réalisée par le Peat Consultants Canada, Ltd. pour la Northwest Territories Association of Municipalities à l'aide d'une subvention accordée par le Programme de démonstration dans les collectivités éloignées d'Énergie, Mines et Ressources Canada.

FEASIBILITY OF FUEL PEAT PRODUCTION AND UTILIZATION AT HAY RIVER AND YELLOWKNIFE, N.W.T.

INTRODUCTION

Peat has been used as fuel for many years in other northern countries, but has not yet been used for this purpose in northern Canada, although large deposits are found here. The technology for fuel peat production and utilization is well developed in Europe, Scandinavia, and the Soviet Union, and horticultural peat has been harvested for many years in southern Canada, but it is not known whether this technology would be directly applicable to communities in northern Canada. Factors such as permafrost, energy requirement, and climate in these communities make it necessary to evaluate the existing technology in terms of these local constraints.

A preliminary inspection of airphotos of peatlands near several northern communities revealed that the peat deposits near Hay River and Yellowknife show the most promise for potential development. The first part of the report deals with the reasons for selection of these two communities, and with an assessment of the suitability of the nearby peat resources for harvesting and utilization based partly on our findings and observations during visits to the sites.

Secondly, the feasibility of fuel peat production at Hay River and Yellowknife is addressed. The technical and economic aspects of fuel peat production in relation to the estimated initial market for fuel peat are discussed.

The third part of the report examines the technical and economic aspects of fuel peat combustion with reference to Hay River and Yellowknife based on information from Finland where the technology of fuel peat combustion is well established.

It is our intention in conducting this study to expose only sufficient facts to support a recommendation to attempt or not to attempt to start fuel peat production in this area. It is not our purpose to perform a detailed inventory of the peat resources, existing energy consumption in the communities, or all possible peat production and combustion systems.

Our discussion of peat production and combustion systems is supported by the latest information on these systems gathered during a recent visit to Finland. During our visit, we examined several peat harvesting operations and peat-fired heating plants, and interviewed peat producers, peat machinery manufacturers, peat-fired boiler manufacturers, and fuel peat consumers.

This report contains the results of extensive calculations of cost and performance estimates of fuel peat production and combustion at Hay River and Yellowknife. As estimates, these figures are not to be regarded as design calculations, and they do not represent in any way guarantees of equipment performance or costs. We assume no liability for any differences which may arise between the estimates in this report and actual equipment performance and costs which may be achieved or incurred in practice.

PART 1 — SITE SELECTION AND RESOURCE ASSESSMENT

SITE SELECTION

A basic premise of this study was that it should address the potential for fuel peat production and utilization at one or two selected communities in the Northwest Territories with an established energy demand now being satisfied at considerable cost. The possibility of using locally harvested peat as an energy source which might provide both cost savings and local employment is to be examined.

Our selection of two communities is based on a report and air photographs supplied to us by Boreal Ecology Services Ltd. [1]. The report summarized an inspection of air photographs taken near Yellowknife, Hay River, Fort Smith, Fort Simpson, and Inuvik. It briefly identified potential energy markets in Yellowknife, Hay River, and Fort Smith. It was indicated to us that, "...of the many peat deposits in the vicinity of the communities, those selected fit predetermined criteria which were:

- distance from all-weather roads
- size of deposit
- access to deposit for harvesting and transport
- natural drainage features
- distance to major communities."

We were supplied with air photos of sites near Yellowknife, Hay River, and Fort Simpson. Our inspection of the photographs confirmed that there are extensive peatland areas in the vicinity of Hay River, and considerable, if somewhat

fragmented, areas of peatland near Yellowknife.

The peatland areas for Hay River include three sites, one 8 km south-west of the town centre, a second site near Grumbler Rapids, 75 km south-west of Hay River and 1 km west of the Mackenzie Highway, and a third site 2 km south-east of Pine Point, or 75 km east of Hay River.

The photographs show two areas of peatland near Yellowknife. The first is 10 km west of town with the highway running through it, and the second is 7 km to the south of the first.

Photos of areas within a few kilometres of Fort Smith were not supplied to us. For Fort Simpson, a series of three low-altitude photographs shows a relatively small area of peatland contiguous with several ponds and lakes which appear to have about 25% of the area of the peatland, making drainage a major problem.

Based on the information available to us and on our general knowledge of these areas from visits in the past, Hay River and Yellowknife appeared to show the most promise as potential fuel peat production and utilization communities, and were therefore selected for this study. The location of the sites is shown in Fig. 1.

Because of the transport distance of at least 75 km between each of the sites at Grumbler Rapids and Pine Point and the town of Hay River, these sites were considered as collateral to the main site close to the town. With respect to the extent of peatland, and based on the photographs and other information available to us, Hay River appeared to have the highest potential for fuel peat supply of all the communities discussed here.

COMMUNITY	POPULATION	POTENTIAL MARKET FOR FUEL PEAT
Hay River	3,400	schools hospital offices/recreation water heating
Yellowknife	10,000	schools offices/recreation city water heating process heat in mines

Table 2. Potential market for fuel peat in the study communities.

SITE NO.	LOCATION	PEATLAND AREA	REMARKS
Hay River			
1	8 km south-west of town centre	1143 ha	4 sections, size range 44-541 ha
2	Grumbler Rapids, 75 km south-west of town	6200 ha	Area is closest to highway. More peatland nearby.
3	Pine Point, 75 km east of town of Hay River	300 ha	Close to town. More peatland nearby.
Yellowknife			
1	10 km west of Yellowknife	135 ha	Consists of many small deposits separated by rocky terrain. Only two deposits more than 15 ha in area.
2	12 km south-west of Yellowknife	69 ha	Consists of two main areas about 42 ha and 27 ha. Adjacent peatland unusable due to division into small, shallow sections by rocky terrain.

Table 3. Peatland areas near the study communities.

However, our selection of Hay River and Yellowknife for this study should not be taken to mean that the other communities would be unsuitable. Peatland is a dominant landscape feature in this area, and, the possibility of locating other potential peat production sites near Fort Simpson, Fort Smith, and other communities should not be ruled out as a possible future exercise.

RESOURCE ASSESSMENT

A number of factors come into play in determining suitability of peatland as a potential source of fuel peat. In this case, we consider the pertinent factors to include:

- potential market
- area of peatland
- depth of peat
- volume of peat
- quality of peat
- location and accessibility
- contiguity of peat deposit area
- drainage potential
- climate
- permafrost
- environmental impact potential

Potential market

Fuel peat has been used for many years for space heating, industrial process heat, and thermal generating stations in northern Europe, Fenno-Scandia, and the Soviet Union. Using peat as fuel in some of these cases has been a necessity because other fuels have been in short supply or very expensive. Peat fuel can be supplied in various forms including milled peat, sods, briquettes, and pellets, depending on the economics and logistics of the harvesting and combustion systems.

The size of heating installation which can use peat as a fuel ranges from a space heater, stove, or furnace in a single-family dwelling to multiple boilers in a thermal electric generating station. It is reported that at Smolensk in the Soviet Union, 4.3 million tonnes per year of peat are used as fuel in a thermal power station of 630 megawatt (MW) capacity [2]. Although it is among the largest peat-fired stations in the Soviet Union, this is only one of many in that country, which has the largest peat reserves and highest peat consumption in the world. At the other end of the scale, in the Falkland Islands in the South Atlantic, individual farmers and householders harvest peat by hand to heat their homes [3].

Table 1 shows a range of peat-fired heating applications based on both actual installations and estimates [1,2,4]. From information in these references and from our associates in Finland we have estimated the annual fuel peat consumption for the heating plants of various capacities, and the area of peatland required to support these levels of consumption. In Finland, one hectare of peatland can supply about 140

tonnes of peat per year as an approximate average figure, but this figure can vary depending on location and weather conditions during the peat harvesting season. One estimate for the annual yield of peat fuel in the permafrost area of northern Ontario is 60 t/ha/year [2]. We have incorporated these figures in Table 1 as a basis for estimating the area of peatland required to support fuel peat consumption for various boiler capacities.

Some possible users of heat produced by burning fuel peat have been identified in reference [1], and these are repeated here in Table 2. We estimate that potential fuel peat consumption for these possible users would fall within the range of values shown in Table 1. Therefore the peat production areas required, as expressed in Table 1, have been used as criteria in this study to evaluate the areas of peatland near Hay River and Yellowknife.

Area of peatland

Peat production systems in common use all require the use of considerable land area in relation to the volume of peat being harvested. This is because, regardless of the production system used, the wet peat as found in its natural state in the deposit has a moisture content of at least 85% by weight, and usually between 90% and 97%. Before the peat can be burned economically, this moisture content must be reduced to less than 50% (as low as 10% for making peat briquettes). Reducing the moisture

APPLICATION	INSTALLED BOILER CAPACITY	PEAK DAILY FUEL PEAT CONSUMPTION	LOAD FACTOR	ANNUAL FUEL PEAT CONSUMPTION	PEATLAND REQUIRED @ 140 t/ha	PEATLAND REQUIRED @ 60 t/ha
Pulp mill	47 MW	249 t/day	90 %	81,200 tonnes	580 ha	1360 ha
Small power plant	40	212	95	73,500	525	1225
Fibreboard mill	12	64	90	21,000	150	350
Residential heating, 680 houses	6	32	43	5,000	36	85
Hospital, 300 bed	4.5	24	43	3,800	27	65
Central heating, commercial building, 110,000 m^3 (1.6 MW peat heat)	2.85	8.5	43	1,300	10	25
Hospital, 50 bed	1	5	43	800	6	15

Table 1. Estimated heating plant sizes and peat production areas required for typical applications.

content requires removal of tonnes of water. Mechanical de-watering by pressing is not practical because it can only handle small quantities of peat at a time, requires the peat to remain in the de-watering press for a long time (i.e. days), and can only reduce the the moisture content to about 65% [2]. Thermal drying in, for example, rotary drying kilns, absorbs more heat than is available from burning the peat being dried if the peat is in its raw, wet state. While some "artificial" thermal drying may be practical, initial drying of the peat must take place in the field by drainage of the peatland and by solar and wind action during the summer months.

As mentioned earlier, we estimate that one hectare of peatland could produce from 60 to 140 tonnes of fuel peat per year, subject to other controlling factors being compatible with peat production. As shown in Table 1, the peatland area near each of the study communities would need to be somewhere between 15 ha and 1400 ha as a minimum to justify considering further investigation.

We examined the air photographs for the sites identified earlier near Hay River and Yellowknife, outlined the peatland areas on the photographs, and measured them with a planimeter. The results of these measurements, with some remarks, are included in Table 3.

Comparing the peatland areas in Table 3 with the range of 15 to 1400 ha, it is evident that Site No. 1 near Hay River has an area (1143 ha) within this range. In fact, the individual sections of the peatland are all substantial in size. Sites 2 and 3 are some distance from Hay River, but their areas (6200 ha and 300 ha) are more than the minimum required.

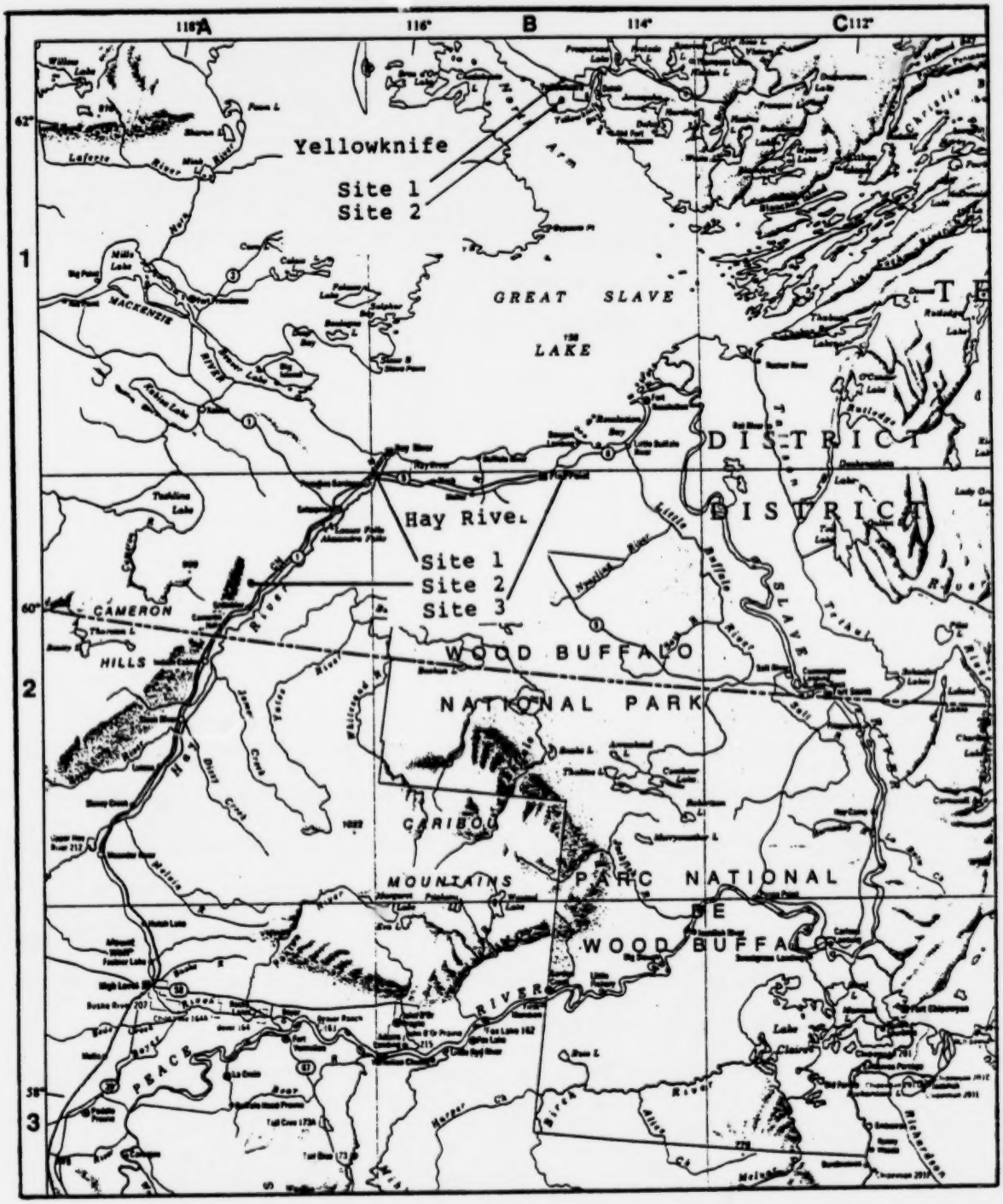


Figure 1. Location of study sites for peat production at Hay River and Yellowknife (Scale 1:2,500,000).

With respect to Yellowknife, although Site No. 1 has a total area of 135 hectares, it is divided into many small deposits of only a few hectares each. Only two of the deposits in this site are over 15 ha in area, being 18.4 ha and 32.8 ha. With reference to Table 1, this order of size would be sufficient to supply fuel for a small hospital, school, or commercial building.

A similar situation exists for Site 2, with 69 ha, divided into two main portions of 42 ha and 27 ha.

In addition to the sites identified from the airphotos, there are other peat deposits in the vicinity of Yellowknife and Hay River, so that the peatlands identified in this study are not the only areas available for possible utilization.

Depth of peat

Peat can vary in depth from a few centimetres to over twenty-seven metres [5]. Age of the deposit, contour of the mineral sub-layer, source of groundwater, and climate are among the factors affecting the depth of the accumulated fossil plant material of which peat consists. In confined peatlands (surrounded by mineral terrain), the peat depth is commonly in the neighborhood of 1-3 m. Contour maps and airphotos can give a rough idea of peat depth, but actual depths cannot be determined at specific sites without on-site investigation.

In the vicinity of Hay River, a sedimentary basin, topographic maps indicate

that surface elevations only vary by a few metres over distances of several kilometres. In the case of Site 1 near Hay River, the airphotos show apparent old beaches running through the peatland with the peat deposited in the lagoons between the beaches. We estimate that the peat depth in all the Hay River sites is variable between 0.5 m and 3 m with large portions between 0.5 m and 1.0m.

The Yellowknife sites are located in depressions in the Precambrian rock. Here we estimate the average peat depth to be about 1.5 m. The actual depth at any point will vary from zero at the boundary between the peatland and the rock outcrop to perhaps 4-5 m in a few places, but the bottom contour of the deposits will be uneven and often shallow.

For viable peat harvesting and to ensure adequate harvesting lifetime for a peat deposit, the peat should be at least 1 m in depth. With respect to depth, it would be possible harvest peat on a small scale at the Yellowknife sites and more extensively at the Hay River sites.

SITE NO.	LOCATION	SURFACE COVER	PEAT STRUCTURE	ASH CONTENT	MOISTURE CONTENT	DEGREE OF HUMIFICATION	PEAT QUALITY
Hay River							
1	8 km south-west of town centre	Low woody shrubs, sedge, moss	Woody fine fibrous	Low - medium	Medium	Medium	Good
2	Grumbler Rapids	Medium to tall woody shrubs, moss lichen	Coarse woody fibrous	High	Medium	Medium	Fair
3	Pine Point	Low woody shrubs, scattered coniferous trees, moss, lichen	Coarse woody fibrous, woody remnants	Medium - high	Medium - high	Low - medium	Fair-poor
Yellowknife							
1	10 km west of town	Low woody shrubs, scattered coniferous trees, moss. Other areas heavily wooded.	Woody fine fibrous, some coarse woody fibres and wood remnants.	Low - medium	High - medium	Low - medium	Fair
2	12 km south-west of town	Low woody shrubs, sedges, scattered coniferous trees	Woody fine fibrous, some woody fragments	Low - medium	High - medium	Medium	Fair-good

Table 4. Summary of peat quality estimates.

Volume of peat

The volume of peat available for harvesting depends not only on the average depth of the peat deposit, but also on the water content, variability of bottom depth, and the harvesting system used. The total of fuel peat available for harvesting is reduced from the original volume of wet peat by shrinkage from draining and drying. An accurate volume estimate is therefore only possible as part of a detailed site investigation, outside the scope of this study. However the importance of this factor can be shown by the fact that if raw wet peat in the deposit has a moisture content of 95%, reducing the moisture content to 50% for burning the peat will remove about 900 kg of water from every cubic metre of raw peat, and the final volume of fuel peat will be much less than the volume of the raw wet peat.

Peat quality

Peat characteristics related to its fuel quality include structure (vegetal composition), ash content, moisture content, and degree of humification (extent of decomposition). High quality fuel peat has low wood content, low ash content, low moisture content, and is well humified. These characteristics provide good heat value and make the peat more economical to process, transport, and handle.

Peat quality can only be assessed accurately for production purposes by means

of a detailed ground survey of the peat deposit. However, inspection of air photographs can reveal typical vegetation components of the surface cover, and this vegetation is usually strongly related to the peat structure beneath. We have carried out this type of analysis for the Hay River and Yellowknife sites, and have assembled the results in Table 4.

From this description of the peat deposits, we can estimate the relative quality of the peat in the various deposits. As shown in Table 4, Site 1 near Hay River, followed by Site 2 and parts of Site 1 at Yellowknife appear to show the best promise of being good quality fuel peat. This is because of their estimated uniformity, low wood content, and relatively low ash content.

We are sufficiently confident in these predictions to recommend further investigation of these sites if other factors appear favorable, but any decision to commence a peat harvesting operation should be preceded by a detailed site investigation.

Location and accessibility

The main factors to be considered here are distance from the heating plant, distance from existing road (or railway), and type of terrain between the peat deposit and existing roads. Distance from the heating plant affects the delivered cost of the peat fuel. Because of the relatively high water content and low bulk density of peat

fuel, the heat content per unit volume of peat is low compared with other fuels, so to transport the heat content from one place to another requires more vehicles or trips than for other fuels. Thus the delivered cost of peat fuel increases more rapidly with increasing transport distance than for other fuels. One estimate [2] indicates that the cost of fuel peat doubles every 150 km between the peat deposit and the heating plant.

Distance from existing roads to the peat deposit and type of terrain are related to cost of road construction to the peat deposit. This cost will in turn be built into the ultimate cost of the fuel peat, so that the longer the access road and the more construction difficulties are encountered, the higher the fuel peat cost.

For the Hay River sites, the terrain is relatively flat, and the distances from existing roads to the peat deposits are short (less than 1 km), so that access to all the sites is excellent. In particular, Site 1 is immediately adjacent to the municipality, so would be very convenient to develop from the access point of view.

For Yellowknife, the highway runs right through the area where Site 1 is located, but the most suitable parts of the area are located about 1 km from the highway over rough, rocky ground with numerous wet depressions between the rock outcrops. For Site 2, the access road would be at least 7 km long over the same type of terrain. Of all the sites, this would probably be the most expensive to gain access to. From the point of view of location and access, Site 1 at Hay River is clearly the best choice, followed by Site 1 and Site 2 at Yellowknife.

Contiguity

The term "contiguity" refers to the extent to which a given peatland is contained within one continuous area, as opposed to being scattered among a number of smaller deposits. One large area is preferable to many small deposits because site preparation, access, drainage, and peat production are all more straightforward and less costly. Also, if the peatland is divided into many small deposits by interruptions from the surrounding mineral terrain, it is likely that the peat depth is highly variable, and that the peat quality is unpredictable from one place to another.

All the Hay River sites are excellent in this respect, with Site 2 (Grumbler Rapids) offering a huge continuous area of peatland. Site 1, near town is subdivided by old beach lines into four major zones, but each one is large enough to be workable by itself.

The Yellowknife sites are much less suitable from this point of view. At Site 1, as measured from the airphotos, in a total land area of 757 ha, 135 ha or 18% of the land is peatland. This peatland consists of 30 individual peat deposits ranging in size from 0.5 ha to 32.8 ha, the average area being 4.5 ha. Only four deposits are larger than 10 ha. Therefore, although there is a considerable amount of peatland overall in this area, it would be questionable to consider any but the smallest possible peat production program here. A peat production operation at this site might be suitable for local demonstration and pilot scale operation, but could not be expected to supply fuel peat for a reasonable lifetime.

At Yellowknife Site 2, while the contiguous area of peatland is somewhat larger (42 ha and 27 ha), the airphotos show frequent rock intrusions in the peatland. These areas may appear contiguous on the surface, but at 1 m beneath the surface, there are quite possibly frequent mineral interruptions (rock) in the peat. Depending on other factors, this site may be capable of supplying fuel peat for a small hospital, school, or commercial/office building.

Drainage potential

Except where hydraulic mining is contemplated, drainage of the peat deposit is an essential first step in the peat production process. There are many uncertainties, both technical and economic, surrounding hydraulic mining [2], so its use is not really considered a viable alternative in this study. For one thing, hydraulic mining increases the moisture content of the peat, and this additional water must eventually be removed, implying several sources of increased cost as compared with other mining methods.

Peatland drainage is carried out by excavating a system of ditches around and through the peat deposit, leading to one or more drainage outlets. This implies that the land surface elevation must drop adjacent to the peat deposit to let the water flow away from the deposit. The drainage system not only carries away water contained in the peat (very slowly), but also allows rainwater and snow meltwater

from the surface of the peat deposit and surrounding terrain to be carried away. Over a period of one to two or three years, the drained peat consolidates and becomes firm enough to allow harvesting machinery to be operated on it.

In areas of low precipitation, peat deposits typically form on flat, level areas or in depressions in the mineral terrain which collect standing water, so that where peat deposits exist there are natural impediments to drainage.

The Hay River Sites are typically underlain by deep fine-grained soils, providing low surface relief. Site 1 (near town) appears to have formed in lagoons between old beaches on the south shore of Great Slave Lake. Over time, the land surface here has risen with respect to the water level in the lake, so it should be possible to excavate ditches (subject to other restrictions) to drain this area.

Site 2 is located adjacent to a network of streams (Swede Creek) which flows into the Hay River just to the east. This would act as a drainage outlet for the peat deposit. Benchmark elevations on the highway near the deposit are all 290 m and near the junction of Swede Creek and Hay River the elevation is 284 m, indicating a gradient with a drop of about 6 m, enough to drain at least 2 m of peat at the bog location.

At Site 3 (Pine Point) map elevations near the deposit are 213 m and drop to 183 m about 25 km to the east, a drop of 30 m. This is a shallow gradient (1 m/833 m) and drainage of this site could be difficult if local contours are unfavorable.

At Yellowknife, as has already been mentioned, the peat deposits are contained in depressions in the rock, which also holds the water. Detailed survey

would be necessary to identify differences in elevation between the depressions, and drainage channels would have to be blasted through the rock to drain off water. Some of the larger, better-quality peat deposits are adjacent to open water which would also have to be drained off to allow peat harvesting. At Site 2, there do not appear to be any streams nearby, possibly indicating that the deposit exists on a low height of land with little overall gradient. This suggests that drainage would require installing a long drainage channel with explosives, with possible adverse economic and environmental implications.

The possible presence of permafrost and its effect on drainage in all the sites will be discussed in a separate section.

In summary, it appears that drainage of Sites 1 and 2 at Hay River would be relatively convenient and economical, possibly more difficult at Hay River Site 3 (Pine Point), and difficult and expensive at Yellowknife Sites 1 and 2.

Climate

Atmospheric climate plays a major role in peat production, as it affects both drainage requirements and peat drying rate during harvesting. The critical climatic components are precipitation and summer temperature, although hours of sunshine and wind velocities also affect drying rate [2].

To determine the suitability of the climate at Hay River and Yellowknife for

peat production, we have consulted a number of sources [7,8,9] and compared monthly precipitation and summer temperatures for Yellowknife and Hay River (data from Fort Resolution) with the same climatic factors for the peat-producing areas of eastern Canada and Finland (see Figs. 2 - 5). The values from eastern Canada are averages of the south shore of the St. Lawrence River in Quebec and north-eastern New Brunswick, which are major peat-producing areas. The values for Finland are averages of the peat producing areas of central Finland.

These climatic factors have a direct effect on snow cover, runoff, soil temperatures, and freeze-up and break-up times for lakes and rivers, which all give a qualitative indication of the suitability of climatic conditions for peat harvesting. A numerical comparison of these and other factors is given in Table 5.

Figures 2 and 4 show that Hay River is just slightly cooler than Finland in the summer, and has much less precipitation, especially during June, July, and August, the peat harvesting season. Finland is cooler but has less precipitation than eastern Canada. Also, there is more difference between the temperature of eastern Canada and Finland than between Finland and Hay River. Table 5 reveals that the summer rainfall for Hay River is less than half that of eastern Canada, and significantly less than for Finland. The mean summer temperature for Hay River (June - August) is about the same as in eastern Canada and slightly higher than in Finland. (This observation is different from what Figure 2 shows, indicating that the effect of temperature and data variations among various sources prevents more precise comparisons). Finally, it should be noted that our temperature and precipitation values

for Hay River are based on data from Fort Resolution, almost 200 km to the north-east, on the shore of Great Slave Lake. We suspect that the summer climate for Site 1 near town would be slightly warmer and drier and for Site 2 at Grumbler Rapids, which is about 70 km inland from the lake, would be significantly warmer and drier than our figures indicate.

Our conclusion is that, although on an annual basis Hay River is cooler than Finland or eastern Canada, the precipitation is much lower and the summer is just as warm, so that atmospheric conditions in Hay River during the summer would be suitable for peat harvesting, especially at Site 2 (Grumbler Rapids).

Figures 3 and 5 show that Yellowknife is cooler than Hay River, but gets even less precipitation. Table 5 indicates that the summer season is slightly shorter and cooler in Yellowknife than in Hay River. We therefore conclude that the climate in Yellowknife would allow some peat harvesting, but that the harvesting season would be a few days shorter and production yields would be lower than for Hay River.

Permafrost

Both Hay River and Yellowknife are situated in the so-called Discontinuous Permafrost Zone, which extends from about 500 km south of Hay River to about 320 km north of Yellowknife [6]. According to Brown [6], Hay River lies on the boundary between the southern fringe of the permafrost region and the northern region of widespread discontinuous permafrost.

Permafrost is a potentially very critical factor affecting the feasibility of peat production, as peat production has not, to our knowledge, ever been attempted in permafrost areas. The quantitative effects of permafrost on peat production can therefore not be precisely predicted. It is possible, however, to examine the characteristics of permafrost and estimate qualitatively how they would relate to the peat production process.

According to Brown [10], in the southern fringe of the discontinuous zone, (i.e. Hay River sites) permafrost is mainly restricted to peat bogs. Its distribution is erratic, and its occurrence is unpredictable. Permafrost occurs in scattered islands a few feet to several acres in extent, a few inches to a few feet thick. In the Precambrian Shield (i.e. Yellowknife sites), there are islands of permafrost in better drained portions of peat bogs.

In spite of many studies and improvements in remote sensing techniques, the existence and depth of permafrost and the depth of the active thaw layer at any given location in the discontinuous permafrost zone is still not possible [6]. We conclude that there is probably some permafrost in all of the Hay River and Yellowknife sites.

According to Johnston [11], permafrost soils are impervious, resulting in poor drainage. Stripping the surface vegetation increases the depth of the active (summer thaw) layer. The moisture content of both organic and fine-grained mineral soils in permafrost is high.

Hardy [11] indicates that recently thawed permafrost leaves lenses of high

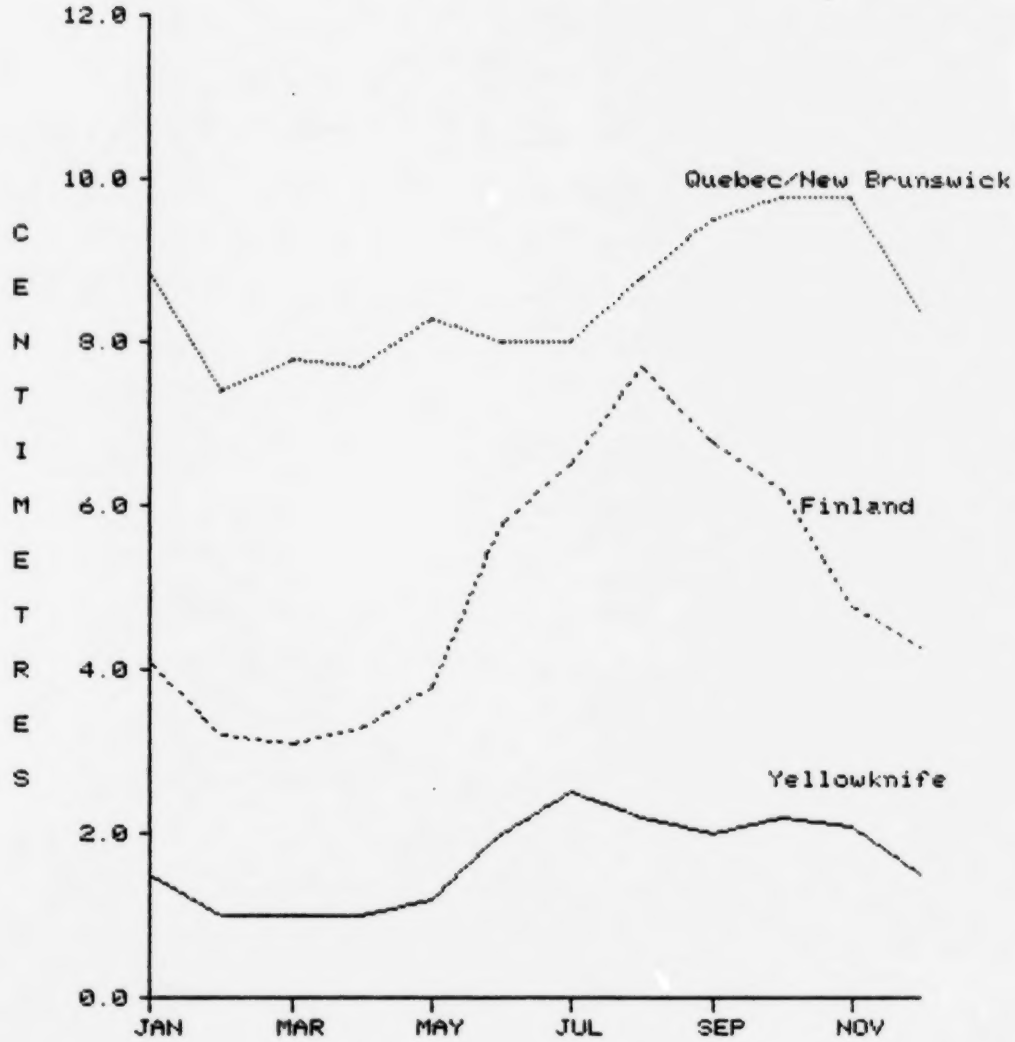


Figure 5. Monthly precipitation throughout the year in eastern Canada, Finland, and Yellowknife.

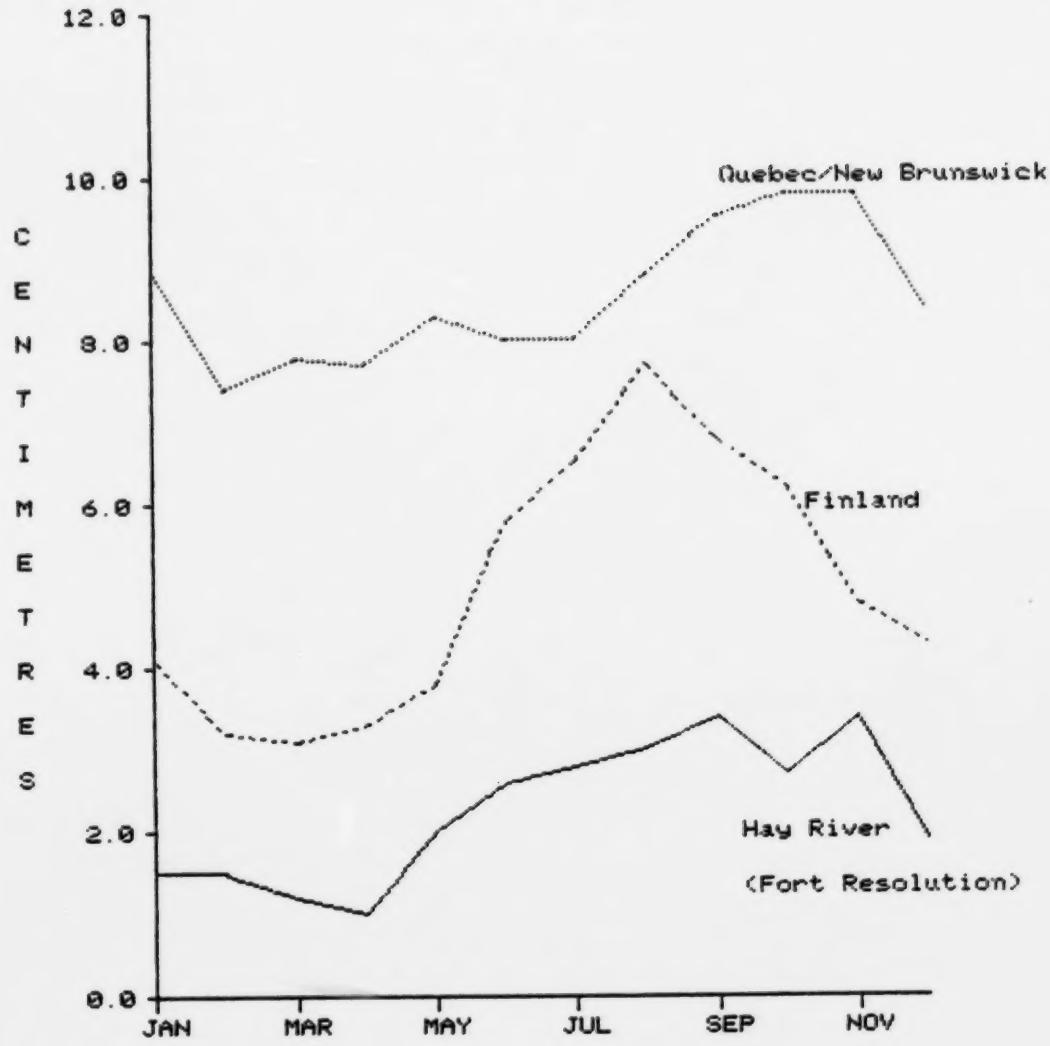


Figure 4. Monthly precipitation throughout the year in eastern Canada, Finland, and Hay River.

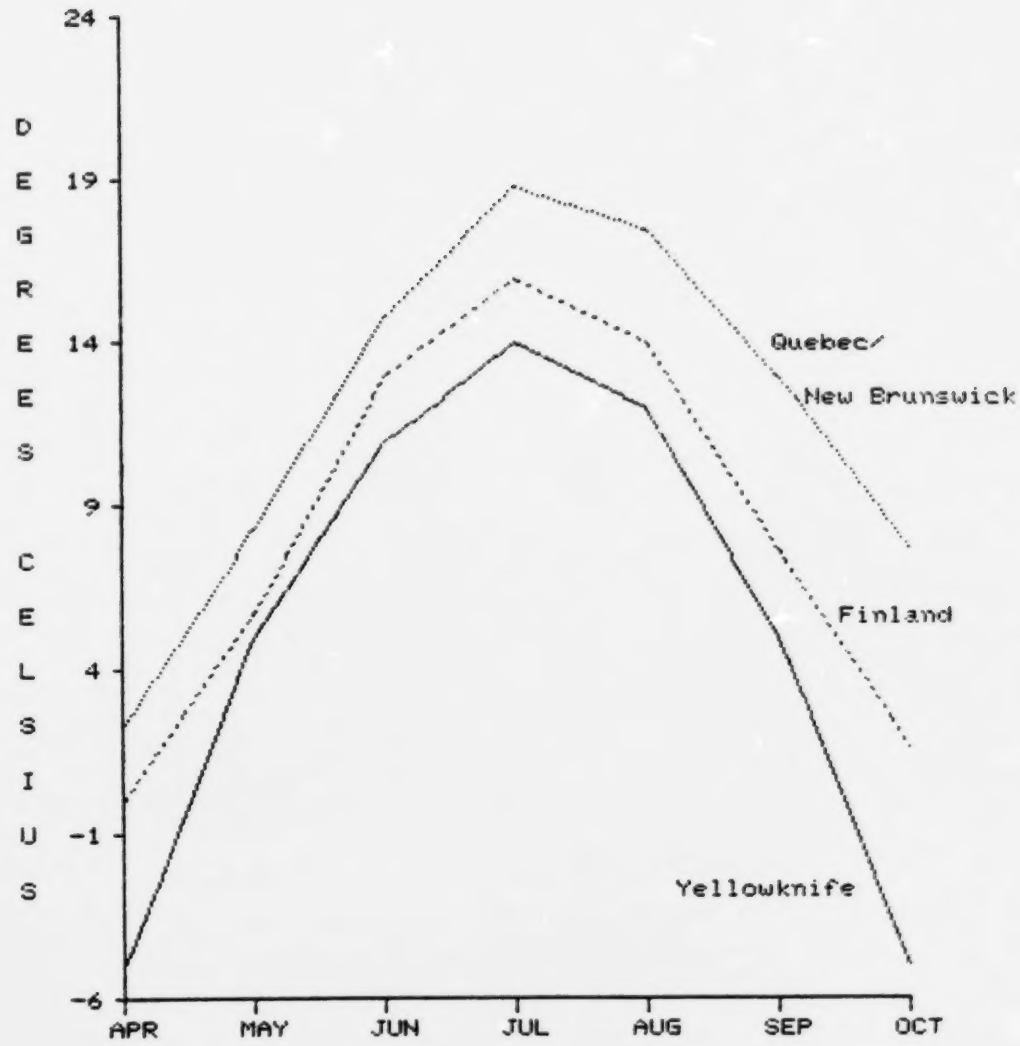


Figure 3. Comparison of mean monthly summer temperatures for eastern Canada, Finland, and Yellowknife.

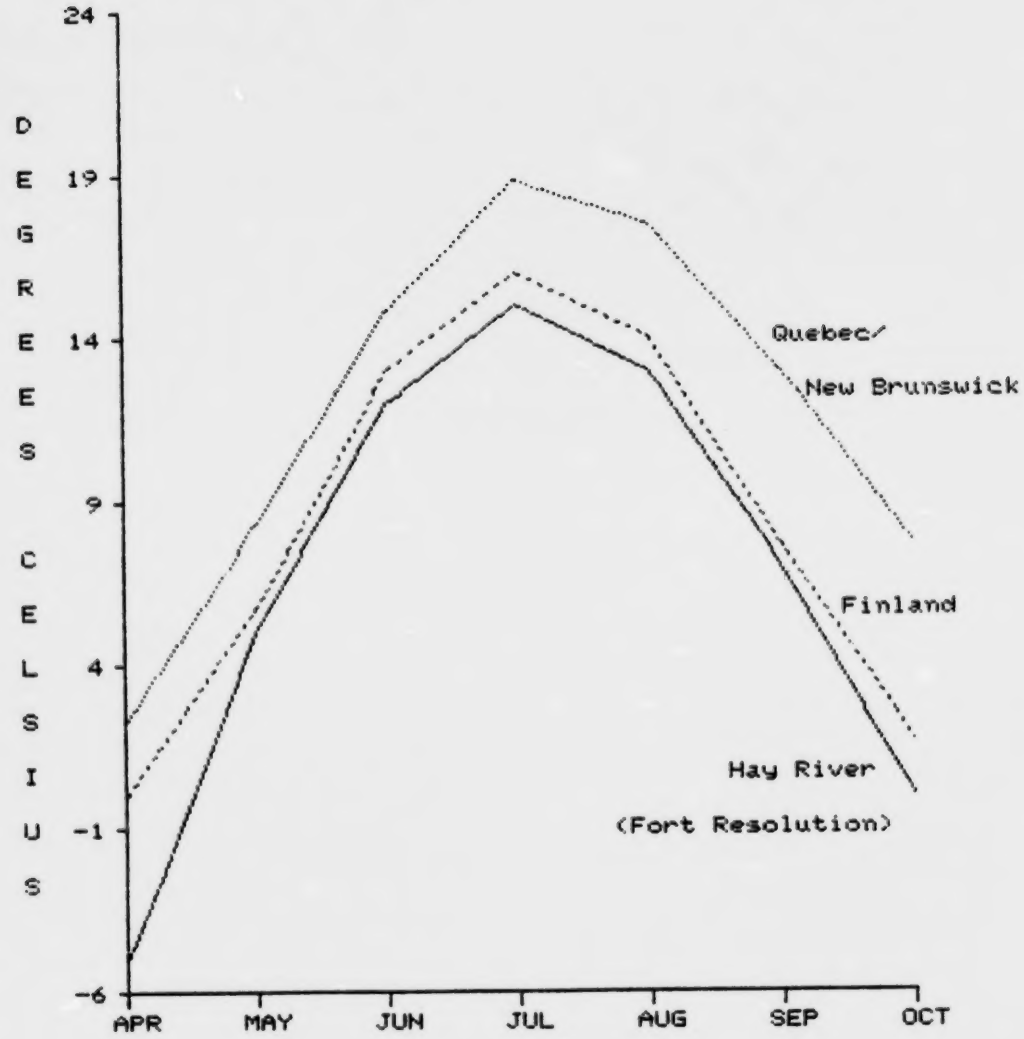


Figure 2. Comparison of mean monthly summer temperatures for eastern Canada, Finland, and Hay River.

moisture content soil. Clearing, stripping off the surface cover and providing surface drainage will invariably increase the rate of deterioration of the permafrost. Structures placed on discontinuous permafrost are subject to differential settlement as thawed soils consolidate under load.

Savage [12] emphasizes that permafrost soils typically have very high water content. Stripping of the vegetation mat can result in large settlements and turn the terrain into a quagmire. Drainage planning must take into account that frozen sub-layers are impervious, causing flooding during runoff. Flowing water thaws permafrost, causing severe erosion.

In another reference, Brown mentions [14] that near Hay River the active layer is 2-3 m in depth, and that the permafrost is about 12 m thick. Pihlainen reported [15] that in 1950 at Giant Yellowknife Mines there was permafrost in islands. In low-lying moss-covered areas, the permafrost table was right under the moss, and when the surface vegetation was cleared the active layer became 2-4 ft deep (0.6-1.2 m). Pihlainen further recorded active layers of 4 ft (1.2 m) at Yellowknife, 5-6 ft (1.5-1.8 m) at Hay River, and 2.5 ft (0.8 m) in low-lying muskeg at Fort Resolution.

These characteristics of permafrost in a peat deposit hold important implications affecting site preparation and harvesting procedures. The presence of ice lenses which collapse when thawing will result in some slumping of drainage ditch walls, necessitating more frequent ditch cleaning during initial drainage to keep the water flowing in the ditches. This should not be a major problem since the drainage

ditches will be mostly less than 1.5 m deep, approximately the estimated depth of the active layer. Unless the active layer is less than 1 m thick, there should be only a few ice lenses encountered by the ditches directly. However, thaw beneath the ditches may encounter ice lenses resulting in slumping.

It will be necessary to have all drainage ditches in place before clearing surface vegetation from the production fields, in order to accommodate the high initial runoff immediately after clearing as the water in the high-moisture-content previously permanently frozen layers is released. During the first season when the vegetation has been cleared, much of the peat deposit will probably be impassable to production equipment, and will remain so until the following winter when the surface freezes.

Initial drainage will probably take longer than in non-permafrost areas because of the shorter summer and probable higher ground moisture content. In the Hay River sites, the frozen fine-grained soils under the ditches where the peat is shallow could be easily eroded as they thaw, if ditch bottom gradients are not carefully controlled to avoid high flow velocities.

After initial drainage and field preparation, a new dry, insulating layer of peat will be established to stabilize remaining permafrost and provide a stable working surface on the production fields. This process may require one or two seasons to complete.

Areas containing peat plateaus and palsas, usually an indicator of the presence of permafrost [6], will develop wet depressions as they thaw. These depressions will

have to be individually drained and filled in during the site preparation in order to establish properly contoured production fields. The size and number of such depressions is unpredictable, and procedures for dealing with them would have to be worked out as an experimental aspect of the site preparation.

In summary, we feel that permafrost would not prevent fuel peat production, but its presence would slow down survey work, site preparation, and drainage. Presence of permafrost in the contemplated peat production sites could only be determined during detailed ground survey work, which would require power drills for peat sampling when permafrost occurs in the peat. There would be increased need for cleaning and repair of drainage ditches, and additional temporary ditches may be required to drain ponds formed by melting of sub-surface ice lenses.

Existing ditching machines in Finland and Sweden now commonly excavate ditches in frozen peat during the winter so would be able to do so at Hay River and Yellowknife. We anticipate that removal of the surface vegetation from the peat deposits will increase the depth of the thaw layer enough to allow production machinery to work in the peat during the summer, although drainage and site preparation will probably take longer than in Finland or eastern Canada.

We can see no reason for permafrost to prevent peat production. However, any peat production project contemplated near Hay River or Yellowknife should be regarded as experimental until established, as there will undoubtedly be unforeseen problems to overcome with new solutions.

Environmental impact potential

The potential environmental impacts of fuel peat production and combustion are by-products of the site preparation, drainage, harvesting, storage, and combustion processes, and will be more fully discussed later in the report. However, the essential factors are summarized here. A thorough analysis of the pollution potential of peat harvesting and combustion,liquefaction and gasification is contained in references [16] and [17], two studies which were completed in 1983.

The potential environmental impact problems can all be avoided in existing peat production and burning facilities with careful planning and supervision of these operations. The potential problems include:

- water pollution
- air pollution
- soil erosion
- ecological effects
- fire hazard
- site rehabilitation

Runoff from a peatland drainage system is really only acceleration of existing runoff. This may result in increase in sediments transported by the water and in increase in acidity of the water. Normally, settling basins are used to collect sediments before the drainage water leaves the area. If necessary, chemical treatment (lime) can be included to control acidity of the effluent.

Minor air pollution can arise from airborne peat dust in a milled peat operation or in the heating plant, and fly ash should be controlled when burning peat. Flue gases from peat combustion contain very low amounts of sulphur as compared with coal and some oils [2].

Soil erosion can be controlled or avoided through planning and supervision of the drainage system.

In comparison with, say, forested land, most peatland is biologically "quite unproductive" [2]. Although peat production changes the total appearance of the deposit itself, there is negligible negative impact on the surrounding environment. In fact, drainage of the peatland can increase the biological productivity of the adjacent marginal terrain, thereby improving the wildlife habitat [2].

As dried peat is intended as a fuel to be burned, there is a significant fire hazard on the production fields and at peat fuel stockpiles especially during warm, dry periods. Drainage ditches provide fire breaks, and ponds can be left undrained to act as water reservoirs in case of fire. Fire-fighting equipment and procedures must be in place, and many operators prohibit smoking in production and storage areas. Spontaneous combustion of peat stockpiles is prevented by monitoring temperature and moisture content of the pile, compacting the pile (milled peat) to expel air, and keeping the ambient air temperature low through outside storage [2].

When the peat in a deposit is exhausted, the site can be converted to other uses or left to slowly revert to its original state. In other countries, the other uses can include agriculture, forestry, recreational parks, or wildlife refuges. The options

for Hay River and Yellowknife would seem to be more limited, as agriculture and recreation may not be viable alternatives, and forestry would have marginal possibilities. The production plan should allow for site rehabilitation for whatever end use is contemplated. Continued use of the land will require maintenance of a controlled drainage system to prevent flooding or over-drying. The production field surfaces should be carefully contoured to prevent formation of stagnant pond water.

SITE INSPECTION

Between June 18 and June 22, 1984, we visited the communities of Hay River and Yellowknife and the five peatland study sites described earlier. Our purpose was to confirm the extent and type of peatland, examine the permafrost conditions, and attempt to identify more precisely some energy markets in the two communities.

Yellowknife Site 1

This site is a collection of small peat bogs occurring in depressions in the Precambrian bedrock. One of the bogs, located just to the south of a new sewage lagoon, was visited on the ground. There appeared to be enough local variation in surface elevation to support drainage of this area, although a planned raising of the level of the adjacent lagoon might interfere with this idea. At the edge of a peat plateau adjacent to a small lake, permafrost was found 30 cm beneath the surface. There was no permafrost in a low-lying sedge-covered area between the peat plateau and the lake, and one metre of peat was found here. We infer that there is 2 m of peat in the adjacent plateau. In general our remarks in the earlier report concerning this site were confirmed by the site visit.

Yellowknife Site 2

This site is about 7 km south of Site 1, and was observed only from the air. We confirmed the earlier identification of the site as peatland. The general topography is

flat, with shallow depressions filled with peat. We feel that the deposits would be shallow (generally less than 2 m deep) with uneven bottom contours, judging by the rock outcrops scattered throughout the deposit. This confirmed our earlier opinion that this site has little potential for peat production.

Hay River Site 1

Located just outside the town of Hay River, immediately to the west, this site was confirmed as peatland. We gained access to the central portion of the area by helicopter, and found permafrost in peat 30 cm beneath the wet surface covered by sedges and low shrubs. The surface peat was black in colour, and composed of a mixture of fine fibrous and colloidal material. Depth of the peat could not be determined without powered drilling equipment, which was not available. However we later learned [18] that an access road and drainage ditch between the new sewage lagoons and the shore of Great Slave Lake cross one corner of this peat deposit, and that 1 m of peat was found at this point. This suggests greater depths near the centre of the deposit.

The area of the deposit extends well beyond the portion visible on our air photographs, so the total area would greatly exceed our original estimate of 1,143 ha. From the air, we could see additional similar areas to the west and south.

The presence of the road across one corner of the deposit would make access to the site extremely easy and relatively inexpensive. Additional roads could probably be built along the old sand beach lines which extend through the area. The presence

of the drainage ditch from the sewage lagoons to Great Slave Lake confirms there would be a suitable drainage gradient for draining the peatland, and excavation would be relatively easy and straightforward.

Hay River Site 2

This site at Grumbler Rapids about 75 km southwest of Hay River, was confirmed by aerial inspection as a large peat plateau area containing many sedge-covered depressions and several small lakes. There are several equally large peat deposits (thousands of hectares) near the Mackenzie Highway and closer to Hay River. Some of these are string bogs, possibly indicating greater peat depths than occur in the peat plateau areas.

In our opinion, this site may be suitable for peat production experimentally, but other more promising sites are located closer to Hay River.

Hay River Site 3

This site, actually located just outside the town of Pine Point, was visited on the ground. The terrain is generally very flat, with the peat deposit in a shallow depression in the mineral terrain. We found only 30 cm of peat over a silty bottom with no permafrost in the peat. The peat was gritty, indicating high mineral content. Depressions nearby, such as borrow pits beside the highway, were filled with water, indicating poor drainage from the area.

These observations suggest that the peat here is of poor quality, shallow, and

INSTALLATION	APPROX. BOILER CAPACITY MW	TYPICAL ANNUAL FUEL CONSUMPTION L/a	ANNUAL FUEL COST $	EQUIVALENT PEAT REQUIRED t/a	PEATLAND AREA REQUIRED, ha 140 t/ha	60 t/ha
Yellowknife:						
Municipal water heating	3.9	645,000	216,000	2,000	15	34
Hospital	6.2	673,400	211,450	2,100	15	35
School, Sir John Franklin	4.4	554,390	NA	1,800	13	30
School, Mildred Hall	3.6	403,210	161,686	1,300	10	22
Northern United Place	NA	643,000	NA	2,000	15	34
Giant Mines[1]	8.8	3,412,500	1,089,000	10,000	72	167
Cominco Mines	NA	NA	NA			
				------	----	----
			TOTAL:	19,200+	140+	322+
Hay River:						
Municipal water heating	NA	318,000	100,000	1,000	8	16
Sports Centre[2]	NA	330,000	60,000	650	5	11
Hospital, H.H. Williams[3]	NA	320,000	NA	1,000	8	16
Mackenzie Place[3]	NA	650,000	NA	2,000	16	32
				-----	---	---
			TOTAL:	4,650	37	75

NOTES: 1. Bunker C oil
2. Propane
3. Estimate

Table 6. Some major energy users in Yellowknife and Hay River and estimated potential requirement for fuel peat.

unsuitable for production. However, if a local market for fuel peat were to become available, this could be confirmed by a reconnaissance survey of the site, which should be augmented by a search for other, more suitable deposits in the area.

Energy market potential in relation to peat resources

Some major energy users in Yellowknife and Hay River were identified and the heating capacities of their boilers, most of which burn diesel fuel, were estimated. Based on information supplied to us on the heating capacity of these boilers, we have estimated their capacity in megawatts. Some information was available on fuel consumption, and we have used this to determine the equivalent amount of peat which would be used if these were peat-fired boilers. This information, shown in Table 6, is intended only to include some of the largest heating installations in each of the two communities, as it is felt that to be viable from the start, fuel peat utilization would have to depend on a few major users. Eventually, if found to be initially viable, the use of peat could expand to include other users, including possibly electric power plants. Table 6 also shows the estimated annual fuel peat demand and the peatland area required to supply peat for each of the facilities, as well as the totals for each community.

As noted earlier, there are only small deposits of peat available near Yellowknife. Our estimate of annual output capacity for Yellowknife Site 1 is only about 1,200 tonnes (20 ha, 60 t/ha). This amount of peat would only be sufficient for part of one of the smaller facilities identified in Table 6. This confirms our earlier

finding that the peat resource near Yellowknife is only sufficient to support a small demonstration project in which production of about 1,000 t/a of fuel peat might be attempted. If successful, this peat could be used to supply part of the heat for a facility like the Sir John Franklin School.

For Hay River, there are at least four major energy users with a total estimated fuel peat requirement of 4,650 t/a (these do not include the electric generating plant which now meets a demand of up to 5 MW). The peatland area required to supply this amount of peat each year is 37-75 ha. Site 1 near Hay River has an area of more than 1,100 ha, so that if other factors prove compatible, there would be an ample source of fuel peat just outside of town for these and other energy users.

There would also be more than enough peat at this site to supply major users in Yellowknife, Pine Point, and other communities near Great Slave Lake.

Table 6 shows that in Hay River, a single-user demonstration project would consume 1,000 t/a of fuel peat, that Hay River could consume at least 4,650 t/a, that the city of Yellowknife might require 5,000-10,000 t/a, and that if fuel peat could be used for mine process heat in Yellowknife, the total demand could exceed 20,000 tonnes per year. This demand would utilize up to one third of the 1,143 ha in Site 1 at Hay River.

SUMMARY OF FINDINGS

We have reviewed the attributes of each of the five sites under consideration as the basis for deciding whether peat resources suitable for production and utilization exist near Yellowknife and Hay River.

From this analysis it appears that Site 1 near Hay River would be the best choice, followed by Site 1 at Yellowknife. Hay River Site 1 is large, close to town, and is estimated to contain good quality fuel peat in quantities large enough to support a variety of potential uses. The site appears to be drainable, and the low surface cover suggests sufficient depth of peat to allow production machinery to operate. Although we cannot predict the location and depth of permafrost, the available information indicates that permafrost would not be a significant obstacle to peat production, although the time required to place the peat deposit in production may be one or two years longer than is normal in eastern Canada or Finland. Our analysis of the climate shows that, except for unpredictable bad weather which occurs everywhere, the production season would be slightly shorter but just as warm and significantly drier than in Finland or eastern Canada. The warm air temperature would be initially offset somewhat by low soil temperatures, but surface soil temperatures should increase after one or two seasons following drainage and site preparation.

At Yellowknife, we consider the possible viability of peat production at either Site 1 or Site 2 to be marginal for a number of reasons. Although there are a few areas where the peat would be of suitable quality for fuel, they are small in relation

to the size required to support any but the smallest of peat-burning installations. Furthermore, drainage and access over the rocky terrain would be relatively difficult and expensive with respect to the potential value of the fuel peat. Because the peat is contained in many small deposits with highly variable surface cover and uneven, rocky bottom contours, the peat quality can be expected to be quite variable, drainage systems would be elaborate and expensive, and the uninterrupted expanses of peatland needed for efficient operation of production machinery are not available. The short summer production season is measurably cooler than at Hay River, eastern Canada, or Finland, and this could be expected to reduce production yields. In comparison to Hay River, the Yellowknife sites are less attractive for an initial attempt at peat production in this area of the country.

For these reasons, we feel that the only possibly viable peat production system at Yellowknife would be a small reference or demonstration project which would be readily accessible to Yellowknife to illustrate peat production techniques. We have chosen Site 1 because of its proximity to the highway, thus minimizing the cost of access. We do not feel that the cost of at least 7 km access to Site 2 over rocky terrain could be justified, even though the continuous area of peatland at Site 2 is greater than at Site 1.

We emphasize at this point that our study is limited to sites which had been pre-selected by others [1], and does not include all the peatland in the neighborhood of the two communities. However, based on our own observations during visits to these areas, we feel that the sites selected are typical and representative. While it is

unlikely that there are larger continuous peat deposits near Yellowknife, the possibility that there are should be investigated because of the apparent relatively large potential energy market in Yellowknife.

Finally, our site visits confirmed that other large peat deposits exist in the vicinity of Hay River, and that there is a good possibility they would be suitable for fuel peat production. Thus the lifetime of peat production and combustion facilities at Hay River would probably be greater than that suggested by the size of Site 1. Also there might be an opportunity in the future to consider the Hay River deposits as a source of fuel for "neighboring" communities, such as Pine Point, Fort Resolution and Fort Providence, or even Yellowknife by shipping fuel peat across Great Slave Lake.

PART 2 — PRODUCTION TECHNOLOGY REVIEW

PEAT AS A FUEL

Fuel peat is produced in Ireland, Great Britain, Germany, Sweden, Finland, and the Soviet Union, and experimentally in eastern Canada. Before peat production was mechanized, peat blocks were cut by hand and stacked to dry, then collected and burned like firewood in stoves and space heaters. More recently, until about 1980, almost all production was in the form of milled peat, a loose, fluffy material with a consistency similar to sawdust. For many years, some milled peat has been dried and compressed into briquettes (about the size of a clay building brick) for home heating with small stoves and furnaces, but these have declined in popularity in recent years.

Experiments have also been done and are continuing in pelletizing, wet carbonization, and gasification of peat for fuel, but these forms of fuel peat have not yet gained commercial acceptance.

Since the late seventies, so-called sod peat has been produced in Finland, and Finnish machinery for this purpose has now been exported to Ireland, Scotland, Sweden, and the U.S.A. To make sod peat, a tractor-mounted machine travels over the prepared peatland surface, excavates, and extrudes the peat into cylindrical or rectangular chunks which are air-dried in the field then collected for storage in stockpiles. Initially, sod peat was more expensive to produce, but due to development of machinery and production techniques, it is now highly competitive with milled peat.

A recent study in Finland [19] has found that while milled peat is suitable for large boilers (district heating and electric generating stations) of a least 5 MW capacity, sod peat is preferable for smaller district heating plants, industrial and commercial buildings, and for other installations from 10 kW to 10 MW. This was confirmed by our own recent visit to Finland where we found sod peat gaining rapidly in popularity and being used in plants up to 100 MW capacity [20].

In our discussions in Finland, we learned that, although the delivered price of sod peat is still about 10 % higher than for milled peat (in terms of cost of fuel heat content), the production cost of sod peat is now lower than for milled peat. This is due to recent improvements in production techniques, and the lower cost is expected to be reflected in lower prices for sod peat in the near future.

Not only is sod peat now competitive in price with milled peat, but it is also drier, cleaner, easier and safer to handle than milled peat. There is less danger of spontaneous combustion in stockpiles. Also, sod peat is suitable for burning in grate-fired boilers typical of smaller installations.

For these reasons, and because the estimated boiler capacity of all heating installations identified in Hay River and Yellowknife is less than 10 MW (see Table 6, following p. 30), we feel that sod peat production would be the most attractive alternative to explore in Hay River, and our calculations have been carried out with this in mind.

PEAT PRODUCTION SYSTEMS

Peat harvesting is essentially a process of removing water from the peat in the field in several stages, then collecting the dried peat in a stockpile.

Following site survey, site preparation and production planning, the peat deposit is drained by means of a ditch network. The machinery for this includes excavators and tractor-mounted ditchers. The ditches are connected to one or more main outlets to allow spring melt-water, precipitation, and much of the free water to be removed from the peat deposit. Settling basins at the drainage outlets trap water-borne sediments. Ditching can be carried out during the winter if necessary, as the machines can excavate frozen peat.

After a drying period of a few months to one or two years, depending on the initial wetness of the peat deposit, the production fields between the ditches are stripped of surface vegetation and contoured with tractor-mounted screw profilers so that the fields have raised centres and their surface slopes towards the ditches. This is to carry most of the rain water and melt water to the ditches before it has a chance to soak into the peat in the production fields.

Following surface profiling, the deposit is ready for harvesting. Milled peat is produced during the summer by loosening a 1-2 cm surface layer and allowing it to dry in the sun and the wind for a day. During the next two or three days, this "milled" layer is turned several times with a light harrow, exposing the underside for additional drying. This brings the moisture content of the peat down to about 50 %,

and the peat is then collected with vacuum harvesters or ridgers and loaders. This equipment collects the milled peat and places it in a stockpile at the edge of the bog. In this form, the peat is ready for burning, and is loaded into trucks or rail cars for transport to the heating plant.

As mentioned earlier, sod peat is produced, also during the summer, with machinery which excavates wet peat and extrudes it through nozzles onto the surface of the ground. The peat emerges from the nozzles in cylindrical or rectangular form about 80 cm thick and breaks into lengths of about 15–20 cm. As the tractor-mounted extruder travels along, the surface of the ground becomes covered with a layer of these peat "sods", which are left to dry for several days. After a few days, a mechanical turner is used to turn the sods over and shake off loose peat. Then, after further drying to a total of 10–15 days, the sods reach a moisture content of about 35 % and are collected and transported to a stockpile at the edge of the bog. Production of up to 140 t/ha is often achieved.

From here, the sod peat can be transported to the heating plant for burning directly in grate-fired boilers, or pulverized (like coal) for use in suspension-fired boilers.

PEAT PRODUCTION EQUIPMENT

For smaller peat production systems, the machinery is driven by conventional farm tractors with four-wheel-drive, dual wheels and 40-80 kW (55-110 HP) PTO output. Industrial systems require special large tracked vehicles matched to the various implements. These vehicles are in the 150-330 kW (200-450 HP) power class.

Some of the equipment for site preparation is manufactured in Canada. This includes farm tractors, ditchers, and levelling screws, as well as front-end loaders and trailers. Other equipment must be imported from Finland or possibly Ireland.

A selection of site preparation and production machinery and its technical specifications is illustrated in Appendix I.

PEAT HARVESTING TECHNOLOGY FOR HAY RIVER/YELLOWKNIFE

A significant difference between the peat deposits at Hay River and Yellowknife and those where peat harvesting is now carried on is the presence of permafrost at Hay River and Yellowknife. This frozen ground condition, about 30 cm beneath the surface in mid-June, is estimated to be continuous at Hay River Site 1, and intermittent at Hay River Site 2 and Yellowknife Site 1, although it is probably continuous within the peat plateaus at Yellowknife.

It is well known that a dry surface layer of peat and vegetation provides insulating cover which preserves, or even enhances, the permafrost during the summer, and that the frozen layer often contains ice lenses. If conventional site preparation methods are followed, the presence of permafrost would cause several unusual results, in our opinion.

First, drainage of the surface (which is quite wet at Hay River Site 1, dry at Yellowknife Site 1) would dry out the surface material, increasing its thermal insulating value and reducing the depth of the active layer above the permafrost. In contrast to thawed, wet peat bogs, this frozen material would provide a very firm base for site preparation equipment to work on during the summer without becoming immobilized.

After the surface vegetation had been cleared, a new, bare, wet active layer would emerge, and it would be deeper than the original active layer, possibly including ice lenses which had previously been permanently frozen. As the ice lenses

melted, the ground surface above them would slump and ponds would form, interrupting the previously frozen ground surface and interfering with machinery traffic. These ponds would require individual drainage and filling to re-establish a continuous production field surface suitable for efficient harvesting of peat. The frequency of occurrence of this situation is impossible to predict, and it may or may not be an important practical problem.

The main combined effect of these factors would not be to prevent peat production, but to increase the time required for site preparation to perhaps three years before peat harvesting could begin. This is not a technical problem, but it could be a financial problem because of the increased time required to pay finance expense or to realize a return on the investment in the peat production system.

The second result of the presence of permafrost would be that, since most sod peat machines excavate peat to a depth of 55-100 cm, and since the active layer would be this deep (perhaps) only late in the summer, the machines would be excavating partly frozen peat which could not be extruded to form peat sods. This problem has already been faced in Finland where a machine has been developed to scrape peat off the thawed surface layer and extrude it into sods, allowing production to start early in the summer before the frost in the peat has completly thawed. This type of machine could be used in Hay River and Yellowknife, in our opinion.

We conclude that sod peat production is technically feasible in Hay River and Yellowknife, but that it might take one or two years extra time to begin production, and that surface-type sod peat machines might be required in order to utilize fully

the summer production season.

Also, the combined effects of summer climate and permafrost on the ground-surface temperature are not readily predictable. However, there is some chance that this temperature would be lower than in other areas where peat is now produced, which would result in longer drying times for the peat sods in the field. Therefore, in our cost calculations, we have used a conservative figure of 60 t/ha, instead of the normal 140 t/ha, as the estimated annual production capacity of the peat deposits.

POLLUTION POTENTIAL OF PEAT HARVESTING

The potential for water and air pollution from peat production is not great, and preventive measures are inexpensive and simple.

Milled peat production has inherently greater pollution potential than does sod peat production. Dried milled peat is very dusty and considerable quantities of the dust can be raised during harrowing and collecting operations. Most of the dust settles on the bog surface again, but some gets blown onto the surrounding terrain. This is not detrimental to the land, as the dust is merely organic plant material which acts as a "soil conditioner", improving the growth habitat for vegetation [2].

Dust is a potential problem for machinery and personnel on the bog. It clogs air filters and radiators, and can be a fire hazard if allowed to collect around hot engine parts. Daily cleaning of equipment is essential. Tractor operators benefit from enclosed cabs with filtered ventilation systems.

Peat dust blows into drainage ditches which then must be cleaned out periodically. Some of the dust is transported in the drainage water, but can be removed in settling basins or in an adjacent lower-level bog before the effluent finally drains into a lake or stream nearby. This prevents decomposition of peat fines in these waters which would lower their oxygen content, affecting health of aquatic wildlife [2].

Much less peat dust is generated by sod peat operations than by milled peat operations, and the potential environmental impacts are greatly reduced.

Peat production is accompanied by some fire hazard around the equipment, in stockpiles, and in the dried surface of the field. A peat fire left unchecked can burn underground throughout the year. Fire prevention measures in the production area are essential to protect the equipment, personnel, the peat resource, and the production operation. Tractors should all carry fire extinguishers, and no smoking is allowed on the site. Water pumps and reservoirs should be available, along with other fire-fighting equipment. Details of fire-prevention and fire-fighting plans should be included in the site-preparation and production plans.

COST OF EQUIPMENT

Sod peat production equipment systems are selected on the basis of the peatland characteristics and on the production capacity required. There are three sizes of system in general use in Finland: the "farmer", or small commercial, size, the small industrial size, and the full-size industrial. Each of these can be augmented with additional components to adjust their output, and with various accessories such as stump millers and collectors, half-tracks, track kits, etc., as necessary. The selection of the equipment items required is part of the site-preparation and production plan.

The costs of typical systems of these three types, delivered in Hay River/Yellowknife, and their production capacities have been estimated as shown in Table 7.

SYSTEM	PRODUCTION CAPACITY t/a	EST. COST DELIVERED
Small commercial	1,330-2,000	$107,000
Small industrial	6,400-8,500	$253,000
Full-size industrial	16,000-21,000	$751,000

Table 7. Production capacity and estimated purchase cost of typical sod-peat production equipment.

These prices are based on 1984 dealer list prices (ex works Finland at current

CLIMATIC FACTOR	FINLAND	NEW BRUNSWICK	QUEBEC	YELLOWKNIFE	HAY RIVER
Annual days precipitation	-	140-160	140-160	80-100	80-100
Annual precipitation, cm	56-65	91	91	20-30	30-40
Summer precipitiation, cm	27-33	45	45	18	18
Snow cover March 31, cm	55	20	35	50	50
Runoff, maximum, month	-	May	May	July	May
average annual, cm	-	50-60	60	15	15
Mean annual temp, °C	2 (Oulu)	5.8	4.7	-6.1	-4.6
Mean temp. May-Sep, °C	12	14.7	12.8	10.1	11.0
Mean temp. Jun-Aug, °C	14.3	16.8	15.2	13.2	16.3
Soil temp, F deg-days over 41° F	-	2250-2500		under 1000	
Lakes, ice-free days	196	220	205	125	125
Rivers, freeze-up	Nov 20(lake)	Dec 10	Dec 15	Nov 10	Nov 15
break-up	May 9(lake)	Apr 20	Apr 25	May 20	May 12

Table 5. Summary of climatic factors and effects for Finland, eastern Canada, Yellowknife and Hay River.

exchange rates for Finnish components) and include estimated freight to Hay River/Yellowknife, 15% duty and 10% federal sales tax (to be effective October 1984).

It may be that some or all of the equipment from Finland could be imported duty-free, which would reduce the cost considerably. A breakdown of the equipment items and pricing is given in Appendix II.

COST OF FUEL PEAT PRODUCTION

Production of fuel peat, as described earlier, would not require all the equipment to be delivered initially, as peat harvesting would not likely commence until the second or third year. By the same token, revenue from fuel peat sales would not start until the second or third year, but a considerable investment would have been required to start up with site preparation, drainage, and planning all required before production could commence.

In order to estimate the total cost of sod peat production, including equipment operation costs, administration, engineering, transportation, and finance, we performed a cash-flow analysis for several possible scenarios. Based on production at Hay River Site 1, we determined fuel peat prices at the stockpile, as well as delivered in Hay River and Yellowknife, which would be the minimum to ensure payback of financing the peat production operation, earn a reasonable profit for the operator, and generate enough cash to replace equipment and/or invest in expansion after six years of operation. This price was compared with the price of fuel oil by taking the cost of Hay River municipal water heating for 1983 at $100,000 for 318,000 L of diesel fuel [18]. This amount of diesel fuel is approximately equivalent in heating value to 1,000 tonnes of sod peat. The estimated annual savings in fuel cost from using peat were then calculated from 1986 to 1991 inclusive, assuming 5% annual inflation for all costs and 15% interest on funds borrowed/invested for the fuel peat production operation. No allowance was made for taxes, royalties, or harvesting rights for the peat itself.

Table 8 shows a sample of these calculations, which include the unit prices in dollars per tonne ($/t), dollars per megawatt-hour ($/MWh), and the equivalent in Finnish currency, Finnmarks per megawatt-hour (mk/MWh), to facilitate comparison with Finnish data.

The results of several calculations of this type are shown in Table 9. From column 1 in the table, it appears that a small commercial system, which could supply fuel for, for example, municipal water heating or the hospital in Hay River, would operate profitably while saving about 20% in heating fuel costs.

From column 2, a small industrial system would not be used effectively if it produced only 2,000 t/a (it has a maximum capacity of 8,500 t/a), and only marginal fuel cost savings would result. These would probably not offset the cost of new heating equipment required to burn the peat.

Column 3 shows that if sales of peat produced by a small industrial system were to be 3,200 t/a in Hay River, the delivered price of peat could be lowered enough to yield about 31% savings in fuel cost compared with diesel fuel, while still supporting a profitable fuel peat production system.

Column 4 shows that a small industrial system producing 3,200 t/a in Hay River could produce fuel peat for Yellowknife, but when the cost of shipping the peat to Yellowknife is included in the peat price, the fuel cost savings would be marginal and would not pay for heating plant installations to burn the fuel peat.

Columns 5 and 6 show that in order to provide substantial fuel cost savings in Yellowknife from peat produced in Hay River, a much larger amount of peat would

SOD PEAT PRODUCTION AND CASH FLOW

Site: Hay River — Infl. %: 5 — Int. %: 15
Size: Small commercial
Output: 1100 t/a — Stockpile price: 85.00 $/t
Trucking .086 $/t/km — (1984) 22.97 $/MWh
Distance 10 km 104 mk/MWh
Destination: Hay River

	1985	1986	1987	1988	1989	1990	1991
Loan balance		175000	165000	125000	60000	0	0
REVENUE:							
Loan/investment	175000	25000					
Sales	0	103084	108238	113650	119332	125299	131564
Total income	175000	128084	108238	113650	119332	125299	131564
EXPENDITURES:							
Survey	10500						
Drainage, main	10500						
Equip operation	16650	18191	19101	20056	21058	22111	23217
Administration	5250	5513	5788	6078	6381	6700	7036
Engineering	21000	2000	2100	2205	2315	2431	2553
Finance int.	26250	30000	24750	18750	9000	0	0
Total costs	90150	55704	51739	47088	38755	31243	32805
Equipment purch	84588	23627					
Loan payments		35000	40000	65000	60000	0	
Total expend.	174738	114331	91739	112088	98755	31243	32805
NET CASH FLOW	262	14015	30515	32076	52654	146710	245469
PEAT FUEL PRICE DELIVERED							
Quantity 1100 tonnes							
Stockpile price $/t		93.71	98.40	103.32	108.48	113.91	119.60
Produced, tonnes	0	1100	1100	1100	1100	1100	1100
Stockpile price	0	103084	108238	113650	119332	125299	131564
Loading, $1.25/t	NA	1516	1592	1671	1755	1843	1935
Trucking,	NA	1043	1095	1150	1207	1268	1331
Total, delivered	NA	105643	110925	116471	122295	128409	134830
Unit price, $/t	NA	96.04	100.84	105.88	111.18	116.74	122.57
$/MWh	NA	25.96	27.25	28.62	30.05	31.55	33.13
mk/MWh	NA	117	123	129	136	143	150
COMPARISON WITH COST OF DIESEL FUEL							
Diesel 318000 l	105000	115762	121551	127628	134010	140710	147746
Peat 1000 t	NA	96039	100841	105883	111177	116736	122573
Peat saves $/a	NA	19724	20710	21745	22833	23974	25173
Accum. saving	0	19724	40434	62179	85012	108986	134159

Table 8. Sample calculation of peat production cash flow and estimate of savings compared with cost of diesel fuel.

	1	2	3	4	5	6
Production system[1]	SC	SI	SI	SI	FSI	FSI
Production (sales), t/a	1,100	2,000	3,200	3,200	16,000	16,000
Heating plant location	Hay R	Hay R	Hay R	Yelknf	Hay R	Yelknf
Price, stockpile[2], $/t	85.00	100.00	70.00	60.00	40.00	40.00
Price, delivered[2], $/t	87.11	102.11	72.11	103.74	42.11	85.36
Annual savings[3], $	22,360	3,612	41,110	1,582	78,600	26,580
Total savings 6 years[4], $	134,159	21,672	246,646	9,494	471,620	159,500

NOTES:
1. SC = small commercial, SI = small industrial, FSI = full-size industrial.
2. 1984 dollars.
3. Estimated average annual fuel cost saving achieved by buying 1,000 tonnes of sod peat instead of 318,000 L of diesel fuel every year for 6 years.
4. Total estimated fuel cost saving for six-year period (1985-1991) per 1,000 t of fuel peat purchased.
5. Calculation of estimate based on assumed inflation rate of 5% and finance rate of 15% over whole period from 1984-1991. Assumes all prices, including diesel fuel, will increase at 5% annually.

Table 9. Estimated fuel peat prices and potential fuel cost savings in Hay River and Yellowknife for 1,000 t/a of fuel peat produced at Hay River Site 1 from 1986-1991.

have to be produced (16,000 t/a) at a lower stockpile price ($40/t, 1984 dollars). This could only be done with a full-size industrial peat production system, requiring a minimum capital investment of $1,135,000 during the first two years, assuming all of the 16,000 t of peat produced the second year were to be sold for over $700,000. In the event that sales or production did not materialize the second year, the total investment required would be closer to two million dollars for start-up capital.

However, columns 5 and 6 also indicate that very large fuel cost savings (almost 60%) could be realized in Hay River in a facility like the hospital or municipal water-heating plant. The challenge would be to sell enough peat each year in both Hay River and elsewhere to absorb the output of this size of system (up to 21,000 t/a).

The delivered price in 1984 dollars for fuel peat, derived from Table 9, ranges from $42.11/t to $102.11/t, depending on the type of system and amount of peat produced and sold each year. Converting these figures to Finnish currency and from tonnes to megawatt-hours gives a price range of 52-125 mk/MWh, compared with diesel fuel at an estimated bulk price of $0.34/L, or 134 mk/MWh. In 1983 in Finland, sod peat cost 49-60 mk/MWh and "light oil" cost 163 mk/MWh. This comparison shows that the peat fuel cost for Hay River/Yellowknife is somewhat higher than for Finland, but within the same price neighborhood. This is to be expected because of the relatively small quantities of fuel peat involved in Hay River/Yellowknife, and also because of the cost of importing and transporting the production machinery from Finland to northern Canada.

PART 3 — PEAT FUEL COMBUSTION

IDENTIFICATION OF FUEL REQUIREMENT

Some space-heating and other heating requirements for both Hay River and Yellowknife were identified earlier in this report (see Table 6). The capacities of the heating plants are estimated to range from 3.6 MW to 8.8 MW.

In addition to space-heating and other heating applications, we have considered the use of fuel peat for electric power generation. Direct combustion of peat in boilers producing steam for turbine generators is considered economical only for power plants with outputs greater than 30 MW [21]. Smaller power plants can use gasified fuel peat to power diesel generators, but peat gasification is still in the developmental stages and is not yet commercially established.

Depending on cost of transport of fuel peat from Hay River, and on possible future development of dependable peat gasification systems, it may be possible in the future to initiate economical electric power generation with fuel peat in Yellowknife. We feel that, at this time, it would not be sufficiently economical or dependable to attempt.

In Hay River, the existing electric power load of 2.5-5 MW is handled by diesel generators. When peat gasification technology becomes better developed, peat gas could be used to drive the diesel generators, and at least 7,000 tonnes of peat per year would be required to meet the existing load.

PEAT HANDLING

The most economical form of delivery of fuel peat is directly from the producer's stockpile to the heating plant on a daily basis. This reduces the storage capacity requirement (and cost) at the plant to the minimum [19]. When it arrives at the heating plant, the fuel peat is dumped into a covered storage bunker equipped with conveyors (push bar, drag, and screw-type) for loading the peat into the boiler. The conveyors include automatic controls which respond to the boiler load to regulate the supply of fuel to the boiler. A schematic illustration of a typical system appears in figure 6 [19].

An alternative to the covered storage bunker would be to establish an open stockpile adjacent to the heating plant and use a front-end loader to transport the peat from the stockpile to the boiler-feed conveyor. Although this would reduce the capital cost of the peat handling system, it would increase the operating cost.

For the heating capacity range identified, the required throughput capacity of the peat-handling system is estimated at 10-100 t/day(30-300 m^3/day). There should be sufficient storage capacity to allow for a weekend's supply of fuel to be contained in the bunker. For example, we visited a 1.6 MW heating plant in Finland where the storage bunker had a capacity of 300 m^3 (100 t).

Trucks are commonly used to deliver fuel peat to the plant, and one truckload typically contains 30 m^3 of peat.

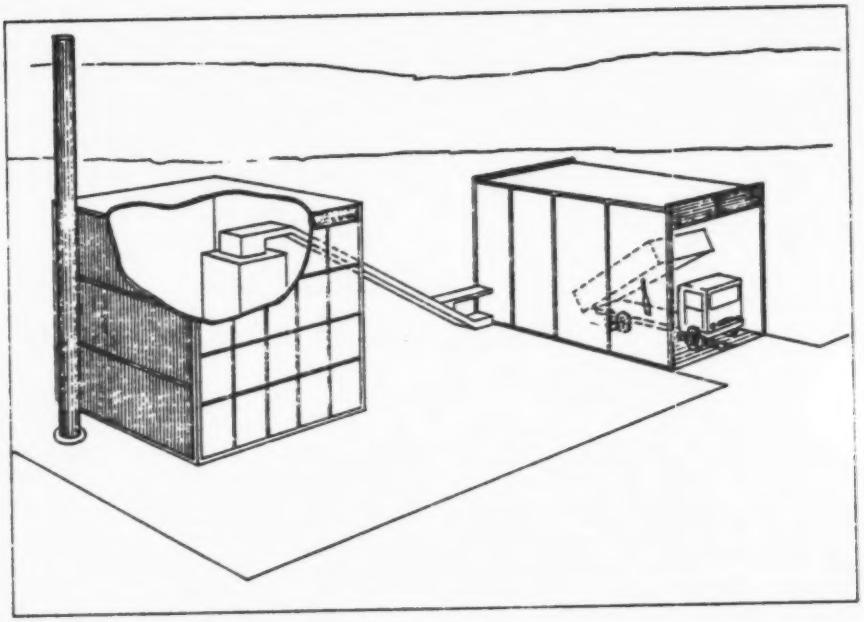


Fig. 6 Typical storage bunker and feed conveyor for peat-fired boiler [19].

PEAT BURNING

Several references [19,22] support our observations in Finland that small boilers under 10 MW suitable for sod peat firing are of the grate type. Larger boilers use pulverized peat burned in suspension, as in cyclone or fluidized-bed burners.

Peat combustion, as compared with wood burning, produces a higher volume of ash which has a lower melting point than wood ash. If the combustion zone temperature is very high, the peat ash can melt, fouling the grate. This can be avoided by cooling the grate by circulating boiler feed water through it. Sloping and movable grates are also successful for burning peat.

Ignition can be accomplished with an oil or gas pilot burner, and typical boilers include an oil burner to carry the variable part of the boiler load, or to heat the boiler when the peat-feeding system has to be shut down for any reason.

Ash from the peat fire is deposited in a wet or dry compartment under the boiler, and is removed periodically by a conveyor discharging into a portable container.

Flue gases can be cleaned by cyclones followed by electrostatic precipitators and/or bag filters, although precipitators have been found to be uneconomical for boilers under 7 MW [19].

One Finnish manufacturer claims that their small boilers (up to 2 MW) require no flue-gas cleaning when burning sod peat, as their particulate emissions are lower than 0.5 g/m^3, a Swedish standard [23].

CANADIAN EQUIPMENT

Several Canadian suppliers are in a position to supply and install wood-burning boilers and fuel-handling equipment, and some of these systems are claimed to be adaptable to peat fuel. One supplier successfully installed a boiler in Lameque, New Brunswick, to burn milled peat for heating a greenhouse. In this installation, the peat was burned "in a pile" on the floor of the combustion chamber. Although the installation was completed and tested, the greenhouse was not completed, so operational data for the boiler under actual loads are not available. The boiler and its operation are described in some detail in reference [24].

Although there are, or have been, two or three other experimental peat-burning installations in Canada in recent years, information about the results of these tests is not readily available at this time. We know of no established, commercially proven peat-burning boiler installation in Canada using Canadian equipment.

Our contacts with several Canadian suppliers of wood-burning boilers revealed that Canadian-supplied burners would be more suitable for milled or pulverized peat, as opposed to sod peat. Although sod peat could be pulverized this would add to the cost, and would not be required if grate-type boilers were to be used.

Scarcity (or absence) of Canadian "off-the-shelf" equipment at this time is conceivably due to the perceived lack of a market for it.

COST OF PEAT COMBUSTION

According to the literature [19], fuel peat in Finland is cheaper than fuel oil, but the capital and operating cost of the boiler and fuel-handling facilities are higher for peat than for oil. The cost of a peat-fired boiler can be up to five times the price of an oil-fired boiler of the same capacity. Operating costs of a peat-fired heating plant are up to 30% higher than for an oil-fired plant [22].

These higher costs arise because of the additional complexity of the peat-handling equipment, higher labour costs, increased maintenance, and greater financing cost for the capital investment which are all required for peat-fired boilers.

These high costs are, in Finland, offset by the low cost of peat fuel, so that the cost of heat produced by burning fuel peat is almost equal to the cost of heat from fuel oil, as shown in figure 7. Furthermore, the owning and operating costs of a peat-fired boiler depend strongly on the fuel quality (moisture and ash content, etc.), on matching the boiler capacity to the heating load, and on the boiler efficiency achieved in practice. Knowledgable operating staff are required to extract the maximum efficiency, and microprocessors are in common use for regulating and monitoring boiler operation [19].

The capital and operating cost of new peat-fired heating plants for the Hay River and Yellowknife installations identified earlier in this study have been estimated on the basis of Finnish experience [19], and the results are presented in Table 10. These figures indicate the magnitude of the estimated capital and operating

INSTALLATION	APPROX. BOILER CAPACITY MW	ESTIMATED ANNUAL HEAT OUTPUT MWH/a	ESTIMATED CAPITAL COST $	ESTIMATED ANNUAL OPERATING & MAINTENANCE COST $
Yellowknife:				
Municipal water heating	3.9	5,200	600,000 - 800,000	151,000
Hospital	6.2	5,400	1,300,000 - 1,780,000	156,000
School, Sir John Franklin	4.4	4,500	1,260,000 - 1,750,000	130,000
School, Mildred Hall	3.6	3,300	800,000 - 1,033,000	96,000
Northern United Place	NA	5,200	600,000 - 860,000	151,000
Giant Mines	8.8	25,600	2,500,000 - 3,500,000	741,000
Hay River:				
Municipal water heating	NA	2,600	300,000 - 430,000	75,000
Sports centre	NA	2,700	300,000 - 430,000	78,000
Hospital, H.H. Williams	NA	2,600	300,000 - 430,000	75,000
Mackenzie Place	NA	5,200	600,000 - 860,000	151,000

Table 10. Estimated capital costs and annual operating costs for peat-fired heating plants in Yellowknife and Hay River.

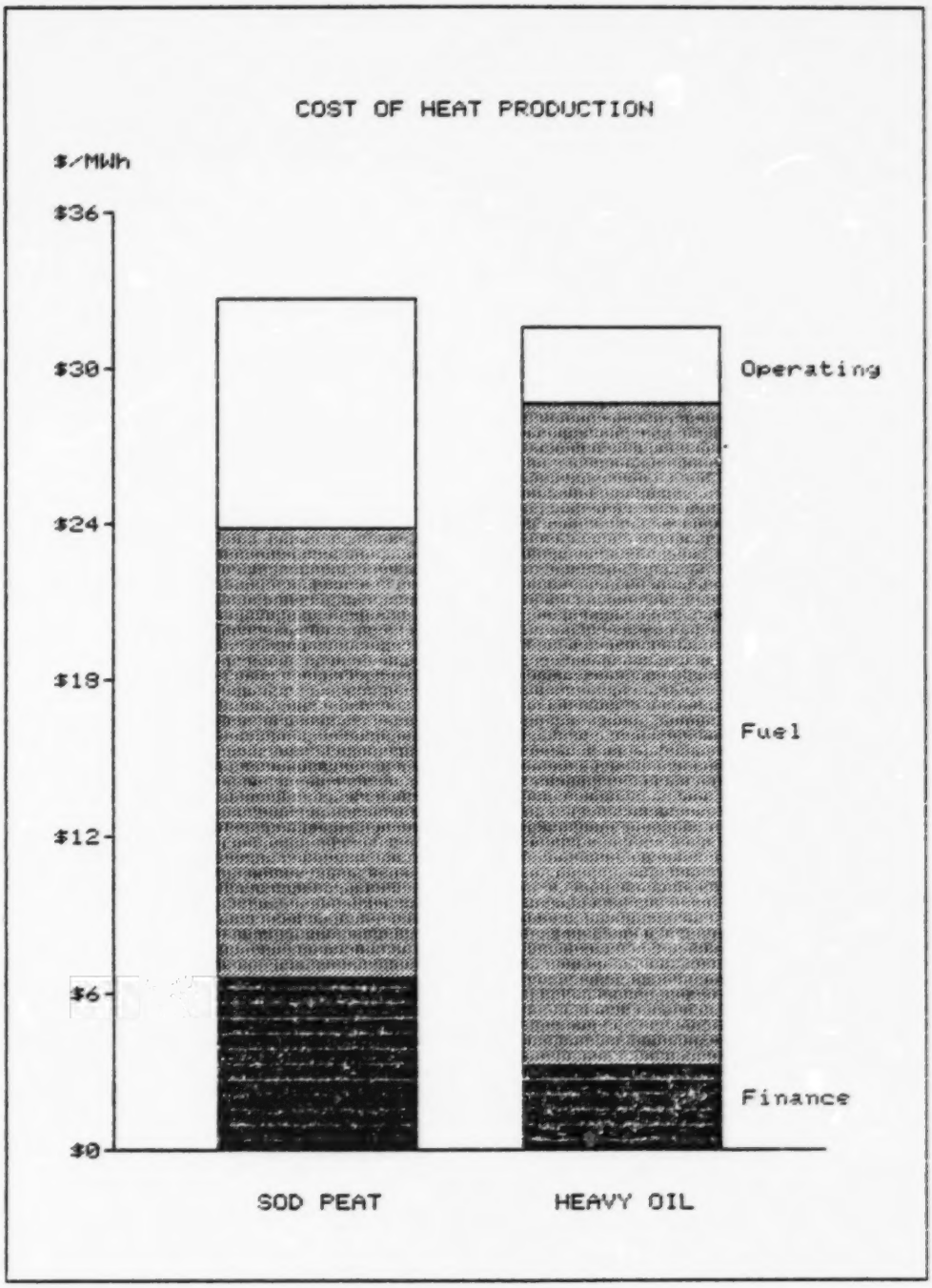


Fig. 7 Comparison of cost of heat production in Finland from peat and fuel oil (19).

costs. A detailed analysis of the estimated savings or extra cost involved in converting from other fuels to peat would require more detailed knowledge of actual owning and operating costs for existing facilities in Yellowknife and Hay River, and is beyond the scope of this study.

However, it should be noted that the capital cost estimates in Table 10 include the cost of new boilers. It might be possible to reduce the capital costs in some cases by retro-fitting peat burners to existing boilers, but this would have to be decided for each case individually.

In general, our information on Finnish experience [19] is that heating with fuel oil and sod peat costs almost the same, the lower cost of fuel peat being offset by higher operating and maintenance costs for peat-fired boilers.

Our study showed earlier that the cost of fuel oil in Finland is higher than in Hay River/Yellowknife (about 22%), and that sod peat fuel would cost roughly the same in Hay River/Yellowknife as in Finland if produced in quantities of at least 16,000 t/a. Therefore, these figures suggest that heating with sod peat in Hay River/Yellowknife would be somewhat more costly than heating with other fuels which are relatively cheap there as compared with Finland.

However, Finnish data show that costs are quite variable from one installation to another, and are strongly dependent on many local factors at each heating plant. Also there would undoubtedly be differences in costs between Finland and Hay River/Yellowknife which cannot be precisely identified or predicted without operating an actual peat-fired heating plant.

In summary, we estimate that considerable fuel cost savings could be achieved if fuel peat could be successfully produced and sold at Hay River. It is not clear whether over-all savings could be achieved by burning fuel peat, especially when the cost and availability of other fuels over the next two decades are unpredictable. Also, in the future, the security of a local source of fuel and indirect benefits to the local economy from fuel peat production may be perceived to offset some of the cost of heating with fuel peat.

In order to establish a more accurate comparison between the cost of heating with conventional fuels and the cost of heating with peat fuel, it would be necessary to set up a monitored peat fuel production and combustion system and gather performance and cost data over a period of at least three years.

TRANSFERABILITY TO OTHER COMMUNITIES

The results of this study could be used as a reference for assessing feasibility of fuel peat production and combustion at other communities in the Northwest Territories. Success of peat production near other communities would depend on the local supply of fuel peat and the size of local markets, and this would have to be determined for each community individually.

If peat production could be established reliably in Hay River, it might be possible to ship peat to other communities from Hay River. This would increase the production volume at Hay River and would allow the stockpile price for fuel peat to be reduced to a minimum, so that the delivered price would be very competetive with that of other fuels.

CONCLUSIONS

1. Both Hay River and Yellowknife represent potential markets for energy proportionate to the estimated fuel peat resource in the area.

2. The climate at Hay River during the summer production season is suitable for peat production as it compares favorably with the climate in Finland and eastern Canada where peat production is already established.

3. It is anticipated that permafrost will be found throughout all the peat deposits evaluated, but that its presence will not prevent production of fuel peat. The time required to drain and prepare the peat deposits for production will probably be greater than normal, perhaps by one or two years, due to the presence of permafrost.

4. On the basis of inspection of air photos and our site visit, there appears to be sufficient good quality fuel peat at Site 1 near Hay River to provide a supply of energy for local needs.

5. Hay River Site 1 is most suitable for fuel peat production because of ease of access, apparently good drainage potential, and proximity to a market and equipment service facilities. Peat depth and quality are estimated to be

acceptable, but are subject to confirmation by reconnaissance and detailed survey.

6. We anticipate that Hay River Site 1 could be drained without major difficulty.

7. It would be technically feasible to produce fuel peat at Hay River Site 1, subject to confirmation of adequate fuel peat depth and quality by reconnaissance and detailed surveys, and to experimental confirmation of peat production machinery operation and peat-drying schedules in the presence of permafrost.

8. Other large peat resources showing good potential for development exist closer to Hay River than Site 2 (Grumbler Rapids). Site 2 does not appear to be immediately attractive for development because of this and because of the small size of the potential market at Hay River in relation to the transport distance between Site 2 and the town.

9. Site 3 at Hay River (Pine Point) is probably too shallow to consider for development, although exposure of a fuel peat market at Pine Point could encourage a more intensive search for suitable peat deposits in the area.

10. There is not sufficient producible fuel peat at the Yellowknife sites to answer a substantial portion of the energy needs of that community.

11. It would be possible to attempt a small demonstration project for fuel peat production at Yellowknife Site 1, recognizing that drainage would be relatively expensive and difficult in relation to the quantity of fuel peat that could be produced.

12. It does not appear attractive to consider fuel peat production initially at Yellowknife Site 2. However, this should be reconsidered later if peat utilization in Yellowknife is ever undertaken (supplied from Site 1 or from Hay River), and data on actual costs and production become available.

13. The climate at Yellowknife is somewhat cooler in the summer than at Hay River, suggesting that reduced peat production yields could be expected at Yellowknife.

14. Although there is some potential for adverse environmental impacts arising from fuel peat production and combustion, these impacts can be avoided or kept to acceptable levels through good planning and project supervision.

15. In Hay River, fuel cost savings up to almost 60% as compared with diesel fuel could be realized by burning sod peat.

16. The price of fuel peat and the fuel cost savings which could be realized by

burning fuel peat are strongly dependent on the volume of peat which could be produced and sold annually. Price can be allowed to drop as production and sales increase.

17. A "small commercial" peat production system could supply sufficient fuel peat for, for example, municipal water heating and/or the hospital in Hay River.

18. A full-size industrial peat production system is estimated to be capable of producing fuel peat in Hay River for shipment to Yellowknife (and other communities) at a price which would offer fuel cost savings to the consumer.

19. If survey and site preparation were started in 1985, fuel peat production could probably begin by 1987, subject to experimental confirmation of our findings.

20. Experimental operation of a fuel peat production system at Hay River would be essential to establish actual cost and performance data to support future planning for fuel peat production.

21. Electric power generation in Hay River and Yellowknife using fuel peat would require gasification of the fuel peat. While this would be technologically possible, it would be more complex, costly, and unreliable than using existing diesel fueled generators at this time. Future increases in electrical power load,

diesel fuel cost, and improvements in reliability of peat gasification would make peat-powered generators a more attractive concept.

22. Combustion of sod peat in grate-type boilers is an established practice in Finland, and this technology would be directly transferable to Hay River and Yellowknife.

23. In Finland the cost of heat production using sod peat is competitive with the cost using fuel oil. As fuel oil is cheaper in Hay River/Yellowknife than in Finland, and sod peat would be slightly more expensive initially in Hay River/Yellowknife than in Finland, heating with peat in Hay River/Yellowknife would likely cost more than heating with existing fuels.

24. The true economics of fuel peat production and utilization in Hay River/Yellowknife could only be determined with actual experience. Competitiveness of peat with other fuels would depend partly on the future behaviour of other fuel costs which may or may not increase in the short term.

25. Canadian boiler suppliers do not appear to offer domestically manufactured small grate-type boilers similar to the proven designs now used in Finland. Material-handling equipment, such as screw conveyors, loaders, and storage bunkers, would be available now in Canada.

26. The data and costs developed in this study could be used as reference material in evaluating feasibility of peat production and utilization in other northern communities, but each community would have to be studied individually with respect to nearby peat resources and potential fuel demand.

RECOMMENDATIONS

1. This study has found that fuel peat production and utilization in Hay River and Yellowknife would be technically feasible at Hay River, subject to confirmation of quality and quantity of the peat resource and any unforeseen problems from local conditions like permafrost. If produced in quantity, fuel peat should be much cheaper than other fuels, and the cost of heat produced with peat should be only slightly more expensive than if produced from other fuels. As actual costs cannot be precisely predicted, they could only be determined through actual experience. The potential benefits of having a local secure supply of fuel, added local employment, and added stimulation to the local economy arising from peat fuel production and utilization are additional attractions.

   For the above reasons, we recommend that a demonstration peat production and utilization project be initiated at Hay River. There would be five main objectives:

   - To confirm the quality and quantity of the fuel peat resource at Hay River.

   - To evaluate the performance of existing peat production technology under local conditions at Hay River.

- To determine actual cost of fuel peat production under local conditions.

- To determine the cost of heat production using fuel peat under local conditions.

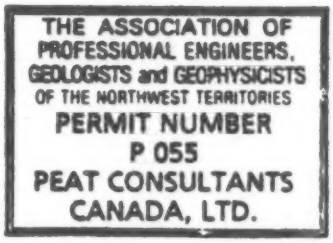
- To expose technical advantages and difficulties of heat production using fuel peat under local conditions.

2. The demonstration project should be divided into three stages: resource inventory, peat fuel production, and peat fuel combustion. The second and third stages would be implemented if the results of the preceding stages are favorable.

3. The project should be undertaken according to a comprehensive plan specifying the peatland survey tasks, peat production plan, heating plant design, installation and operation, monitoring capital and operating costs, and control of potential environmental impacts from drainage effluent and flue gases.

4. The demonstration project should be managed and coordinated by a competent, experienced authority on peatland survey, fuel peat production, and fuel peat combustion.

5. A major feature of the project should be a series of detailed reports documenting the technical and economic performance and results of all stages of the project.



Respectfully submitted,

PEAT CONSULTANTS, CANADA, LTD.

John R. Radforth

John R. Radforth, P.Eng.

ACKNOWLEDGEMENTS

This feasibility study has been conducted under contract to the Northwest Territories Association of Municipalities. We gratefully acknowledge the initiative of this organization in undertaking this project, and the funding support provided by the Remote Community Demonstration Program of the Department of Energy, Mines and Resources of the Government of Canada. We also appreciate the knowledgable assistance and input provided by our associates, Dr. N. W. Radforth who has assisted with the airphoto interpretation, and Mr. Mikko Valli of Peat Consultants, Finland, Oy who has contributed his detailed knowledge of the peat production industry in Finland.

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APPENDIX I

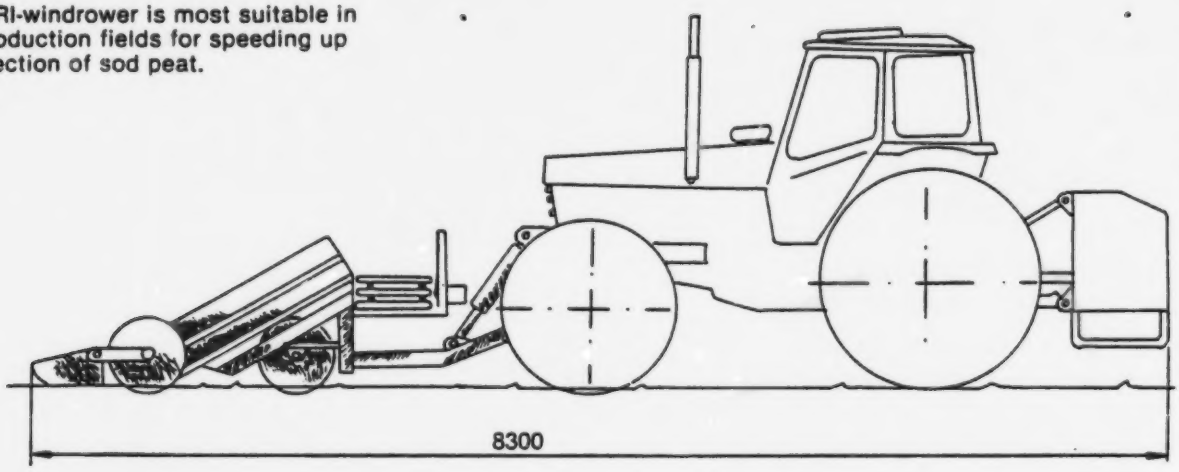
Machinery for site preparation

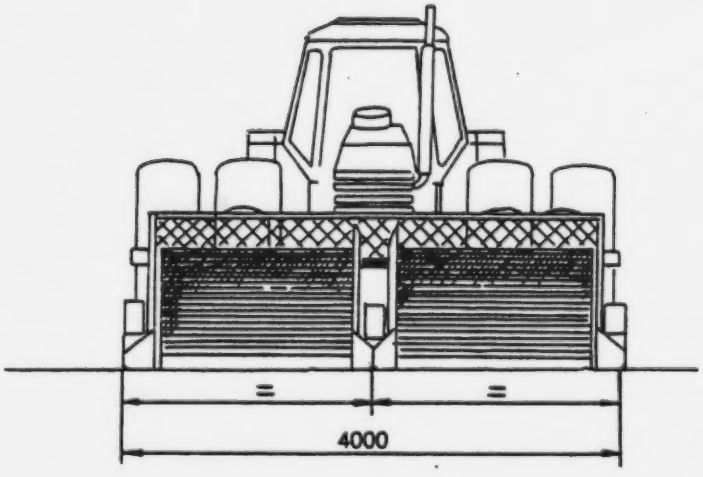
and sod peat production

MERI-WINDROWER KA-4,0

MERI-windrower KA-4,0 can be mounted to crawlers or ordinary wheel tractors. Mounted at the front of the tractor, windrowing can be started at the full production field without any extra arrangements.

The MERI-windrower is most suitable in large production fields for speeding up the collection of sod peat.





TECHNICAL DATA:

Mounted to a crawler or wheel tractor

Power demand	30 kW
Working speed	2000—6000 m/h
Working width	4000 mm
PTO	540 r/min
Transmission	hydraulic/mechanical

Principal measurements

Length	8300 mm
Width	4000 mm
Height	1250 mm
Weight	2310 kg

Manufacturer:

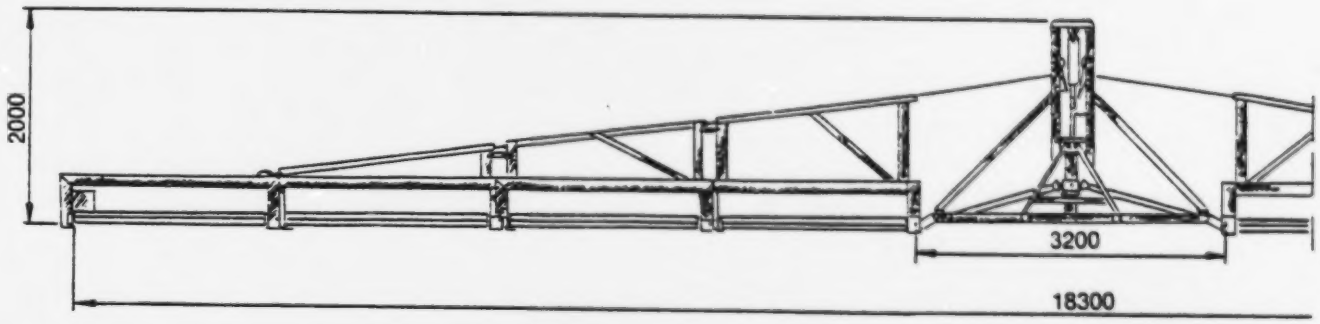
SUOKONE OY

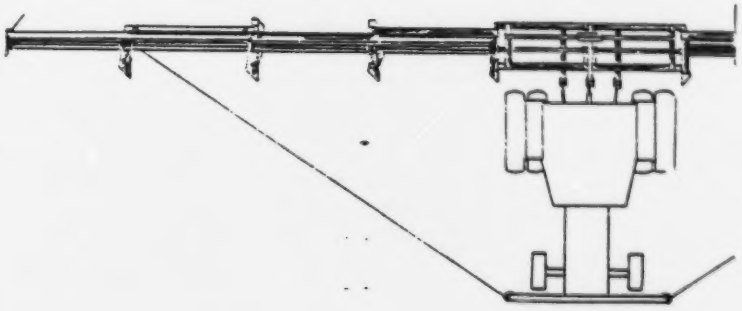
SF-88110 Korholanmäki
Tel. 986-47645
Tel. Int. + 358 86 47645
Telex 33174 suoko sf

Agent:

MERI-SOD TURNER KN-18

Sod turner KN-18 covers the entire width of the field in one single run; the flap shaft lifts every sod from the field and throws them lightly back to the ground.
It also separates the loose peat and gives a clean and high-quality final product.





TECHNICAL DATA:

3-point attachement

mounted to a crawler or wheel tractor	40—60 kW
Power demand from the tractor	10 kW
Working width	18.3 m
Working speed	2—6 km/h
PTO	540 r/min

Principal measurements:

Width	18300 mm
Height	2000 mm
Weight	1425 kg

Manufacturer:

SUOKONE OY

SF-88110 Korholanmäki
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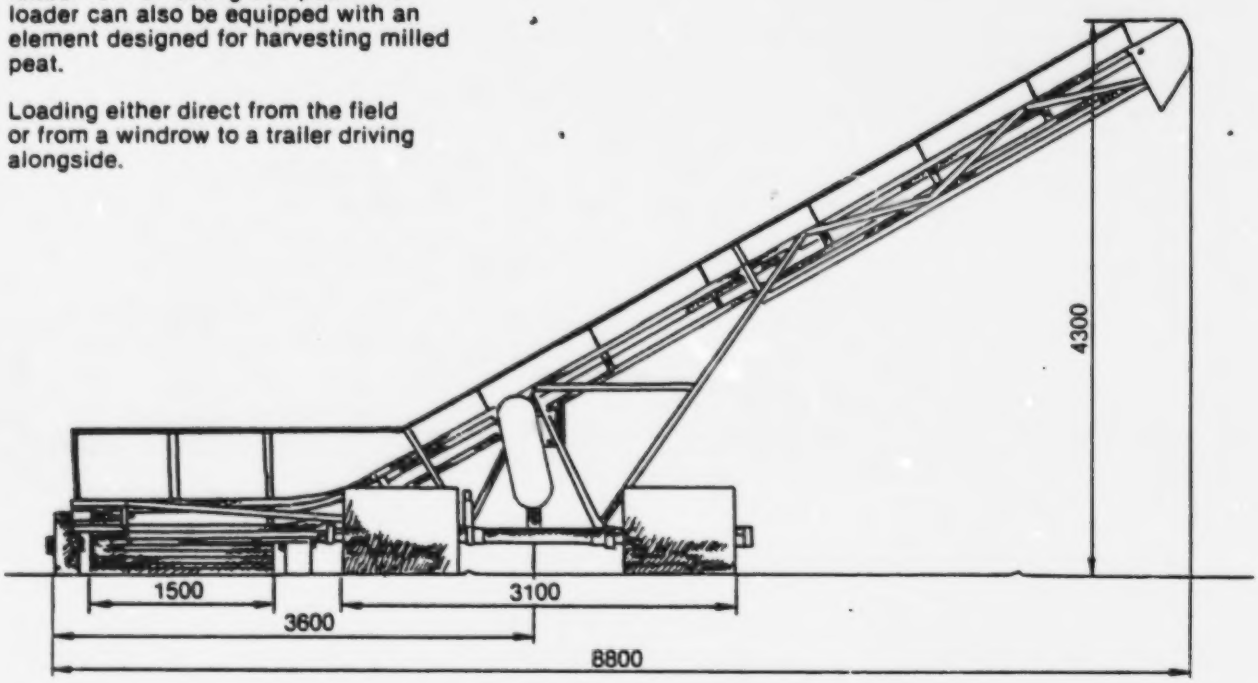
Telex 33174 suoko sf

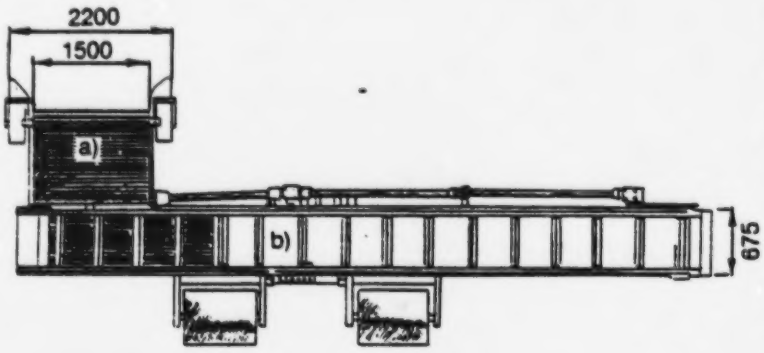
Agent:

MERI-LOADER KU-2,0

MERI-loader KU-2,0 is a 3-point mounted loader for harvesting sod peat. The loader can also be equipped with an element designed for harvesting milled peat.

Loading either direct from the field or from a windrow to a trailer driving alongside.





TECHNICAL DATA:

a) tube belt
b) bucket conveyor
3-point linkage

Power demand	50—60 kW
Loading capacity	150—350 m³/h
Working width	2000 mm
Working speed	1500—6000 m/h
Loading height	4200 mm
Transmission	mechanical
PTO	540 rpm
-size	ø 1⅜" — 6 splines

Principal measurements

Length	3800 mm
Width	8800 mm
Height	4300 mm
Weight	2260 kg

Manufacturer:

SUOKONE OY

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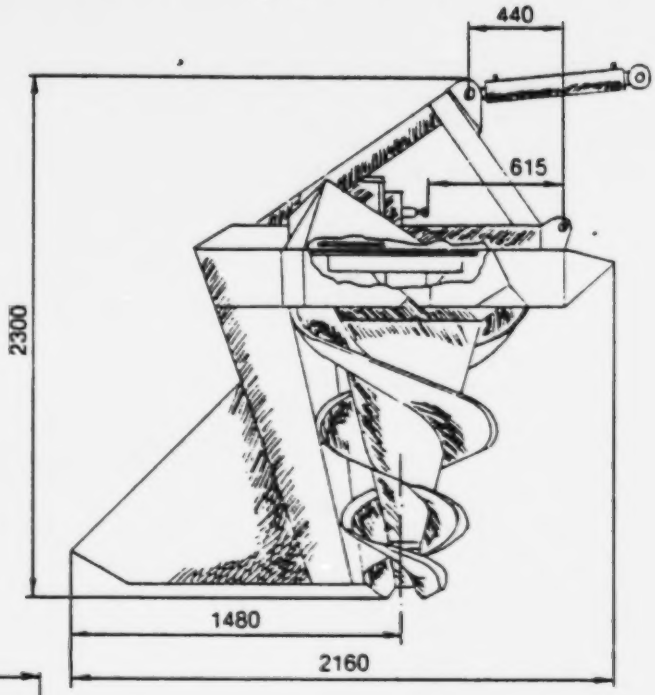
Telex 33174 suoko sf

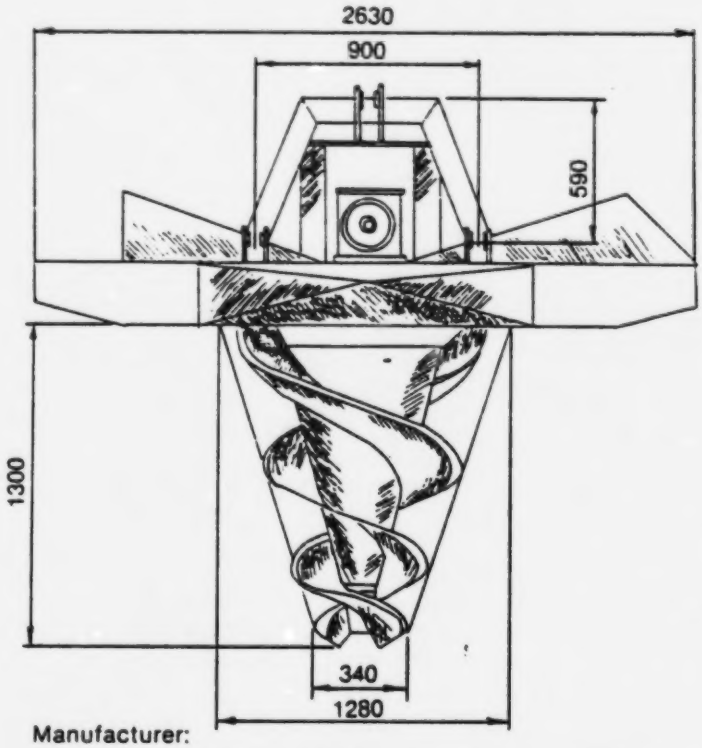
Agent:

MERI-DITCHER OJ-1,3 K

MERI-OJ-1,3 K is a screw type ditcher which is also very suitable for ditching of frozen and wooded bogs. It is also extremely well suited for pre-draining in the winter.

This ditcher type is suitable for clearing of old ditches, too. The excavated peat flies onto both sides of the ditch spreading out evenly.





TECHNICAL DATA:

Mounted to a crawler or a powerful farm tractor

Power demand	80—100 kW
Ditching efficiency	100—400 m³/h
Working speed	200—2000 m/h
Ditch side angle	20°
Screw edge	Imacro steel
Power transmission	mechanical

Principal measurements:

Length	2160 mm
Width	2630 mm
Height	2300 mm
Weight	1000 kg

Manufacturer:

SUOKONE OY

SF-88110 Korholanmäki
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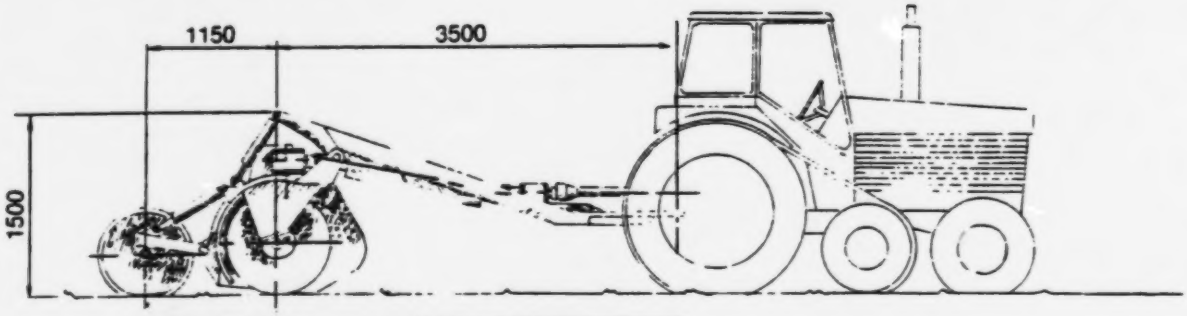
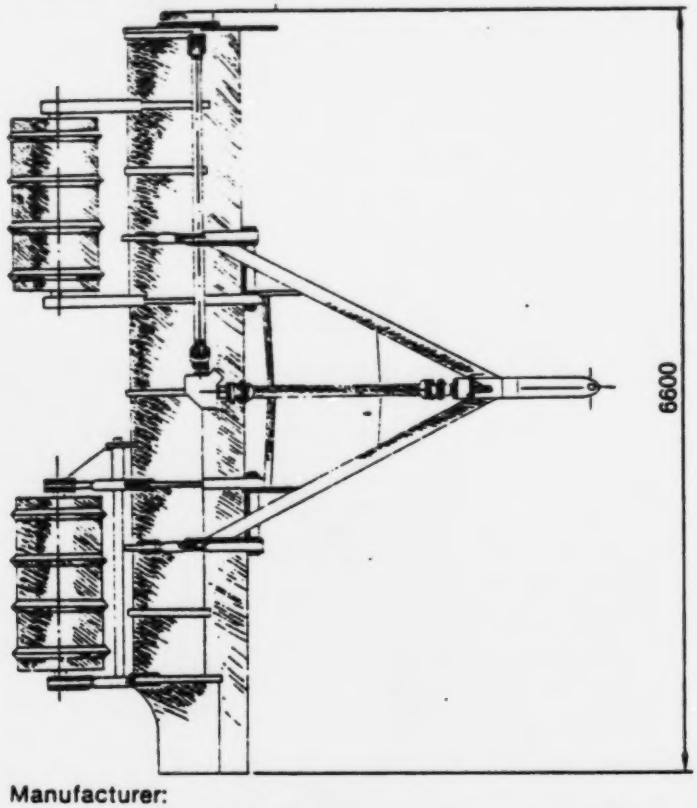
Telex 33174 suoko sf

Agent:

MERI-SCREW LEVELLER RT-5,7 M

Equipped with mechanical transmission, the MERI-screw leveller can be mounted either to a crawler or to a farm tractor. The screw leveller is designed for clearing peat bogs and for annual preparation of peat production fields. In addition, the screw leveller is most useful in preparing new farm land.





TECHNICAL DATA:

Mounted to a crawler or a powerful farm tractor

Power demand	80—120 kW
Working capacity	0,3—1,5 ha/h
Working speed	500—3000 m/h
Working width	5700 mm
Screw diameter	950 mm
Power transmission	mechanical
PTO	540 or 1000 rpm

Pricipal measurements

Length	5100 mm
Width	6600 mm
Height	1500 mm
Weight	3020 kg

Manufacturer:

SUOKONE OY

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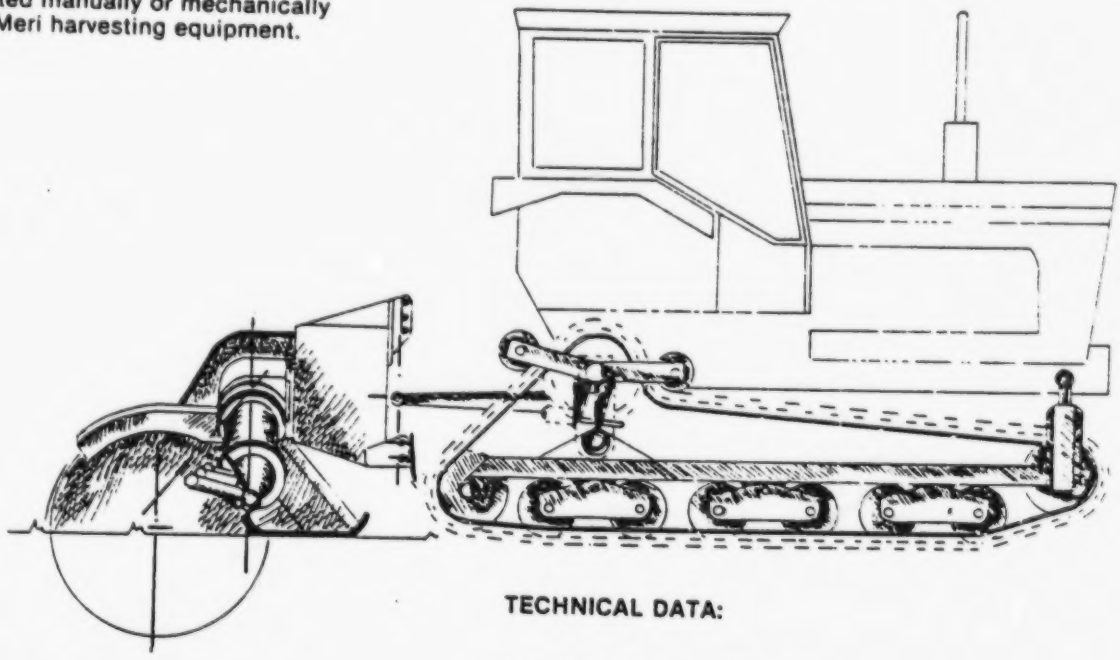
Agent:

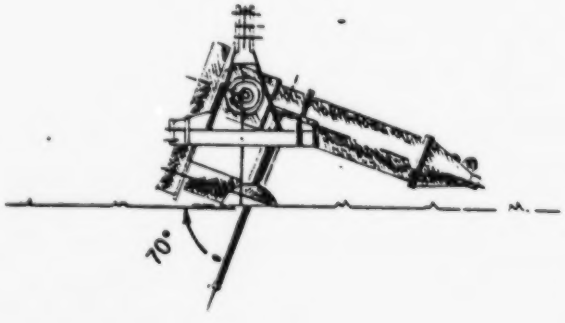
MERI-SOD PEAT MACHINE PK-1S PK-1

The sod peat machine is a tractor mounted, easily transportable machine, which makes it possible to produce sod peat both on small and large areas.
The disc type cutter breaks the peat and throws it into the extruder. Solid sods fall down on the bog and after drying for 10 to 15 days, depending on the weather conditions, the sods can be collected manually or mechanically with the Meri harvesting equipment.

NEW

The machines can be equipped with a new drum compression unit, when they can be used even on bogs with plenty of trees. Sod diameter ⌀ approx 65 x 55 mm, speeds up drying and gives more harvests per season (see fig.).





TECHNICAL DATA:

Mounted to tractor by 3-point attachement

	PK-1S	PK-1
Power demand	90—110 kW	60—80 kW
Working speed	700—1500 m/h	700—1500 m/h
Output (calc. at 45 % moist. cont.)	20—25 m³/h	15—20 m³/h
Cutting depth	550 mm	550 mm
Sod diameter	ø 80 mm	ø 80 mm
Number of nozzles	5	3
PTO shaft speed	540/1000 rpm	540/1000 rpm
Principal measurements:		
Length	2000 mm	1850 mm
Width	2150 mm	2000 mm
Height	1460 mm	1400 mm
Weight	950 kg	780 kg

Manufacturer:

SUOKONE OY

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Agent:

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APPENDIX II

Purchase cost estimates for peat production machinery

Production system: Small commercial.

The following estimate is based on 1984 prices and current exchange rates.

QTY.	DESCRIPTION	MANUFACTURER	MODEL	PRICE
	Base machine			
1	Ditcher	Suokone	OJ-1,3K	15,470
1	Levelling screw	Raussinmetalli	2.5	5,525
1	Sod peat machine	Suokone	PK-1A	5,083
	Turner			
	Ridger			
1	Collector	Turveunsa	3	5,525
1	Spare parts			4,000
	Total f.o.b. Finland			$ 35,603
	Duty 15 %			5,340
	Total			$ 40,943
	F.S.T. 10 %			4,094
1	Tractor (Canadian)			45,000
	Total			$ 90,037

Freight:		
	Base machine	
1	Ditcher	5,000
1	Levelling screw	3,000
1	Sod peat machine	3,000
	Turner	
	Ridger	
1	Collector	5,000
1	Tractor	1,000
	Total freight	17,000
Total cost delivered		$ 107,037

Production system: Small industrial.

The following estimate is based on 1984 prices and current exchange rates.

QTY.	DESCRIPTION	MANUFACTURER	MODEL	PRICE
	Base machine			
1	Ditcher	Suokone	OJ-1,3K	15,470
1	Levelling screw	Raussinmetalli	4 m	12,600
1	Sod peat machine	Suokone	PK-1	12,820
1	Turner	Raussinmetalli	9 m	2,200
1	Ridger	Pala		6,630
1	Collector	Pala	14	24,310
1	Spare parts			8,000
	Total f.o.b. Finland			$ 82,040
	Duty 15 %			12,306
	Total			$ 94,346
	F.S.T. 10 %			9,435
2	Tractors (Canadian)			120,000
	Total			$ 223,781

Freight:

	Base machine	
1	Ditcher	5,000
1	Levelling screw	5,000
1	Sod peat machine	3,000
1	Turner	1,000
1	Ridger	3,000
1	Collector	10,000
2	Tractor	2,000
	Total freight	29,000
	Total cost delivered	$ 252,781

Production system: Full-size industrial

The following estimate is based on 1984 prices and current exchange rates.

QTY.	DESCRIPTION	MANUFACTURER	MODEL	PRICE
1	Base machine	Suokone	TR-450	194,480
1	Ditcher	Suokone	OJ-1,5K	19,448
1	Levelling screw	Suokone	RT-6,0H	17,680
1	Sod peat machine	Suokone	PK-2	29,835
1	Turner	Suokone	KN-18	12,155
1	Ridger	Suokone	KA-4,0	23,205
1	Collector	Suokone	KU-2,0	18,785
3	Trailer			23,868
1	Spare parts			10,000
	Total f.o.b. Finland			$ 349,456
	Duty 15 %			52,418
	Total			$ 401,874
	F.S.T. 10 %			40,187
4	Tractors (Canadian)			240,000
	Total			$ 682,061

Freight:		
1	Base machine	20,000
1	Ditcher	5,000
1	Levelling screw	5,000
1	Sod peat machine	5,000
1	Turner	2,000
1	Ridger	5,000
1	Collector	8,000
3	Trailer	15,000
4	Tractor	4,000
	Total freight	69,000
Total cost delivered		$ 751,061